US008794167B2

(12) United States Patent
Takizawa et al.

(10) Patent No.: US 8,794,167 B2
(45) Date of Patent: Aug. 5, 2014

(54) SEWING MACHINE

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(73) Assignee: **NSD Corporation**, Nagoya-shi (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/812,589**

(22) PCT Filed: **Jun. 23, 2011**

(86) PCT No.: **PCT/JP2011/064464**
§ 371 (c)(1),
(2), (4) Date: **Jan. 28, 2013**

(87) PCT Pub. No.: **WO2012/014610**
PCT Pub. Date: **Feb. 2, 2012**

(65) **Prior Publication Data**

US 2013/0125802 A1 May 23, 2013

(30) **Foreign Application Priority Data**

Jul. 28, 2010 (JP) 2010-169856
Mar. 28, 2011 (JP) 2011-071144

(51) **Int. Cl.**
D05B 49/00 (2006.01)
D05B 47/00 (2006.01)

(52) **U.S. Cl.**
USPC **112/242**; 112/254

(58) **Field of Classification Search**
USPC 112/241-250, 302, 254, 255
See application file for complete search history.

(56) **References Cited**

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Primary Examiner — Ismael Izaguirre
(74) *Attorney, Agent, or Firm* — Edwards Wildman Palmer LLP

(57) **ABSTRACT**

There is provided a needle thread tension controller that can control a magnitude of tension on a needle thread for each stitch, that can draw the needle thread with a slim chance of occurrence of a thread break, that easily, accurately detects occurrence of the thread break when the thread break has occurred, and that does not cause any excess or deficiency of a quantity of accumulated thread, which would otherwise be caused by drawing a needle thread. There are provided an upstream grip section **40** and a downstream grip section **60** for gripping a needle thread and a turning section **80** for turning the needle thread. In a torque control zone, rotating force is imparted to a turning arm in accordance with a torque value.

20 Claims, 48 Drawing Sheets

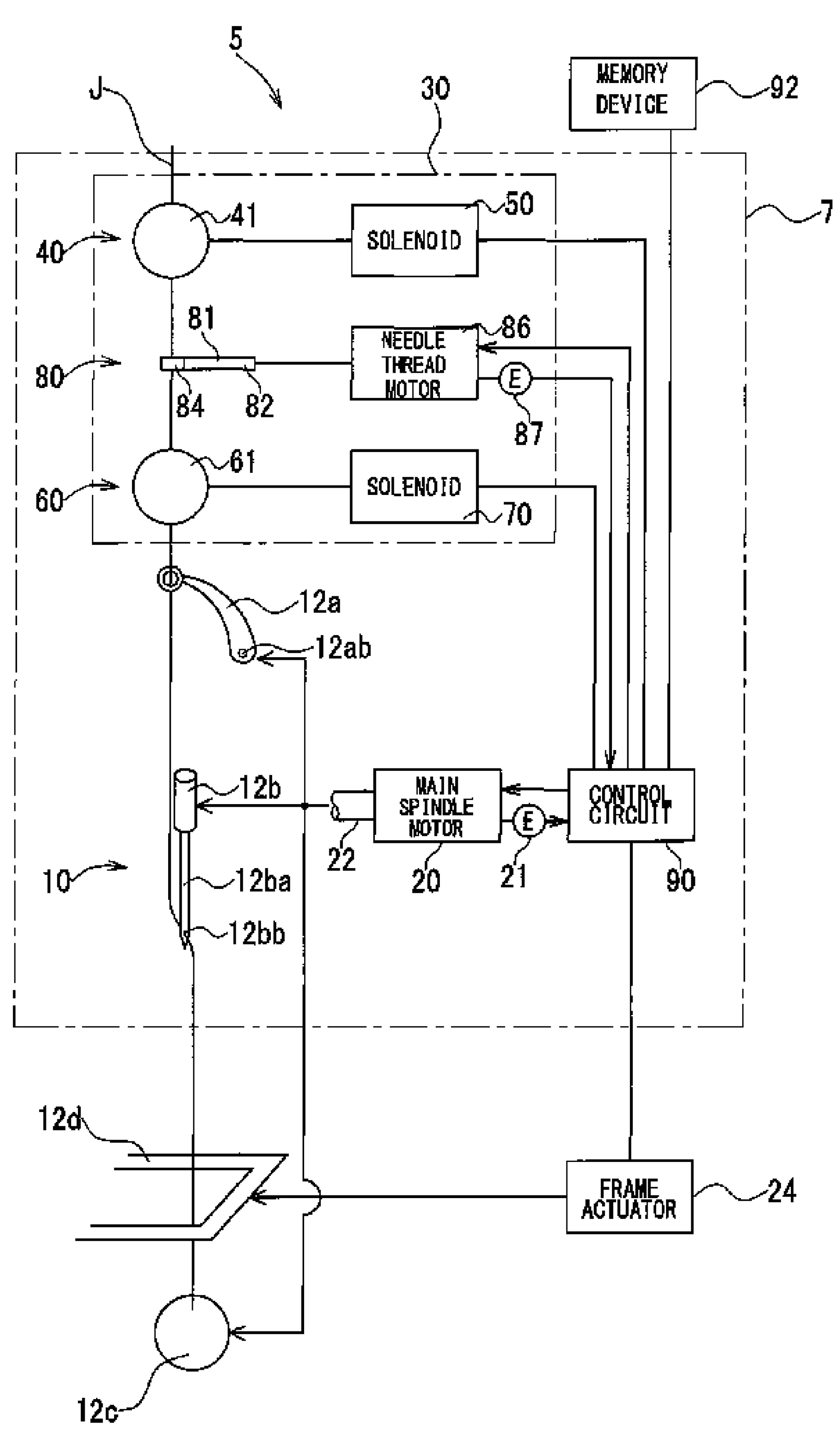


FIG. 1

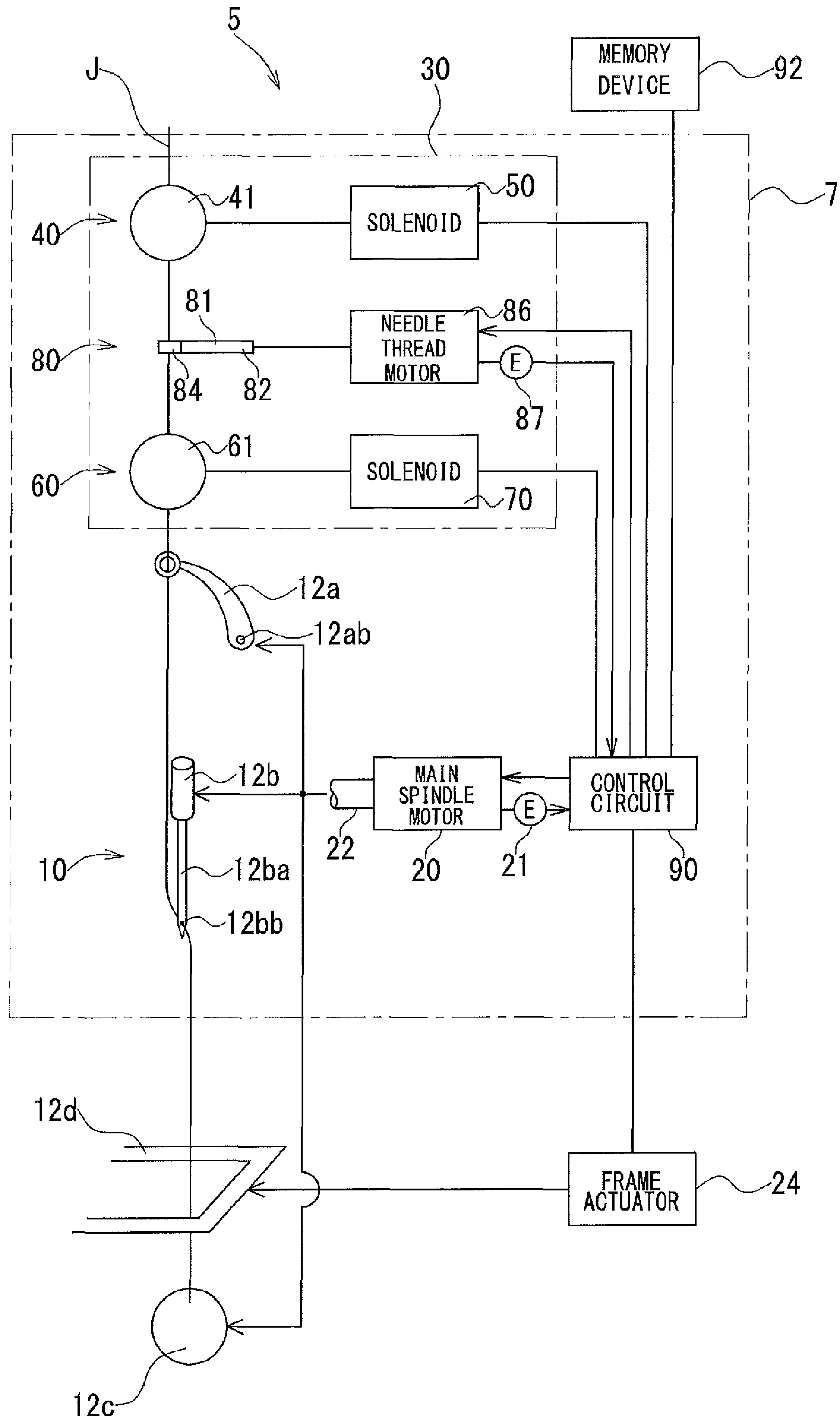

5
J
30
MEMORY DEVICE
92
7
41
SOLENOID
50
40
81
NEEDLE THREAD MOTOR
86
80
84
82
E
87
61
SOLENOID
70
60
12a
12ab
12b
MAIN SPINDLE MOTOR
CONTROL CIRCUIT
E
22
20
21
90
10
12ba
12bb
12d
FRAME ACTUATOR
24
12c

FIG. 2

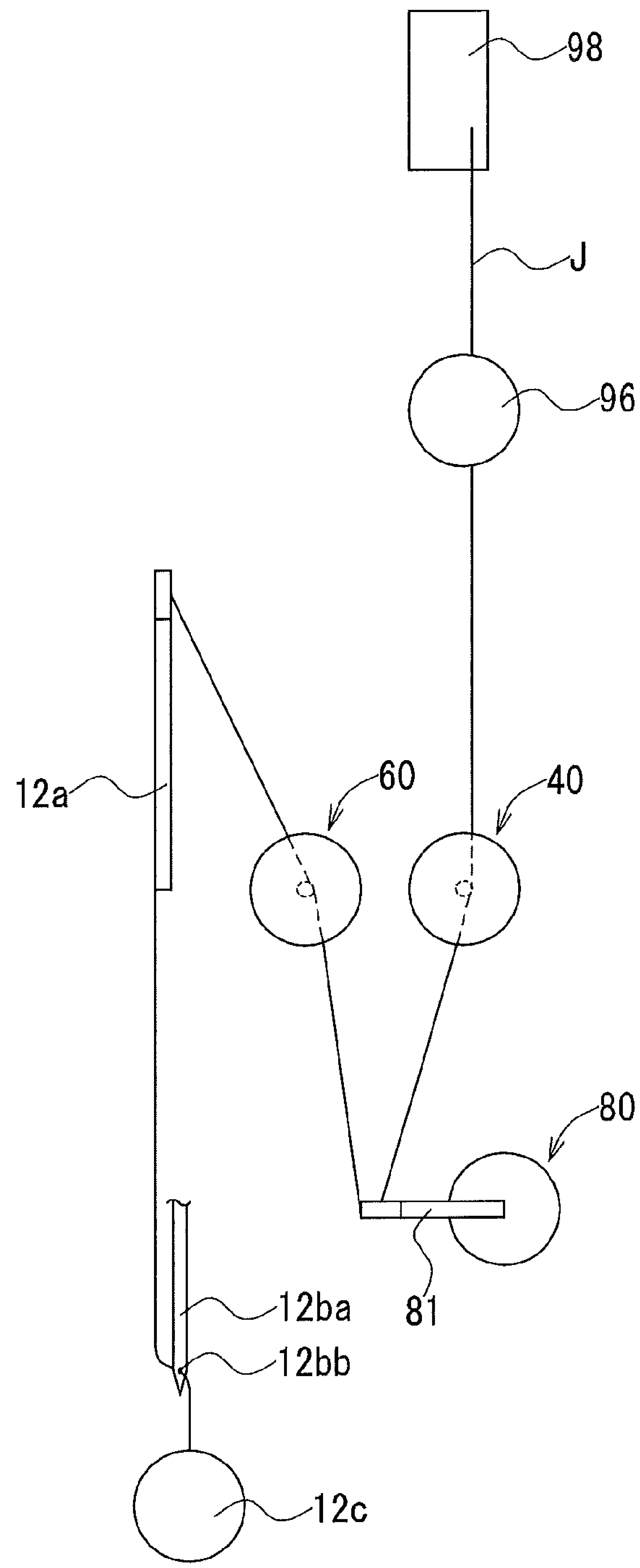
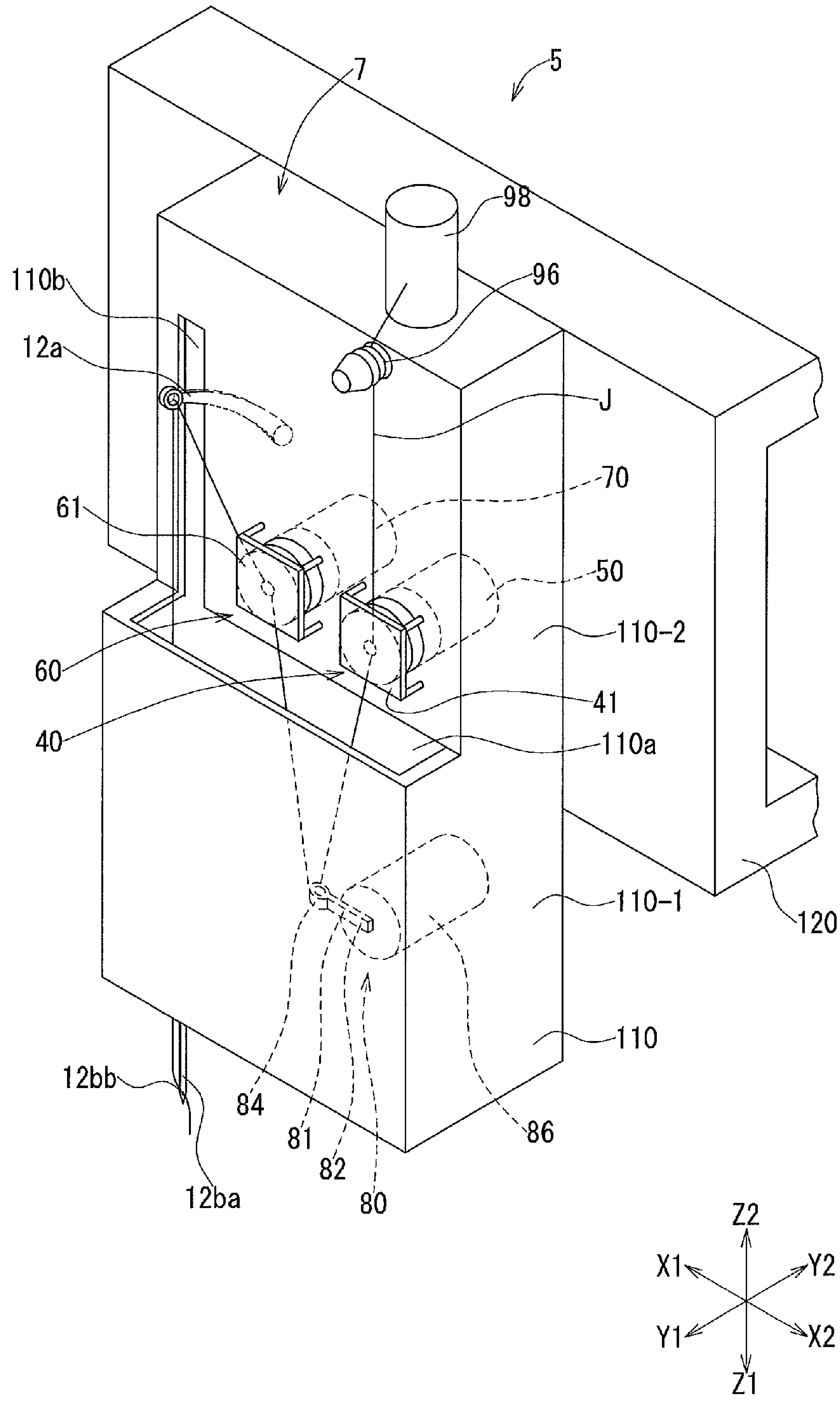


FIG. 3



5
7
98
96
110b
12a
J
70
61
50
110-2
60
41
40
110a
110-1
120
110
12bb
84
81
82
80
86
12ba
Z2
X1
Y2
Y1
X2
Z1

FIG. 4

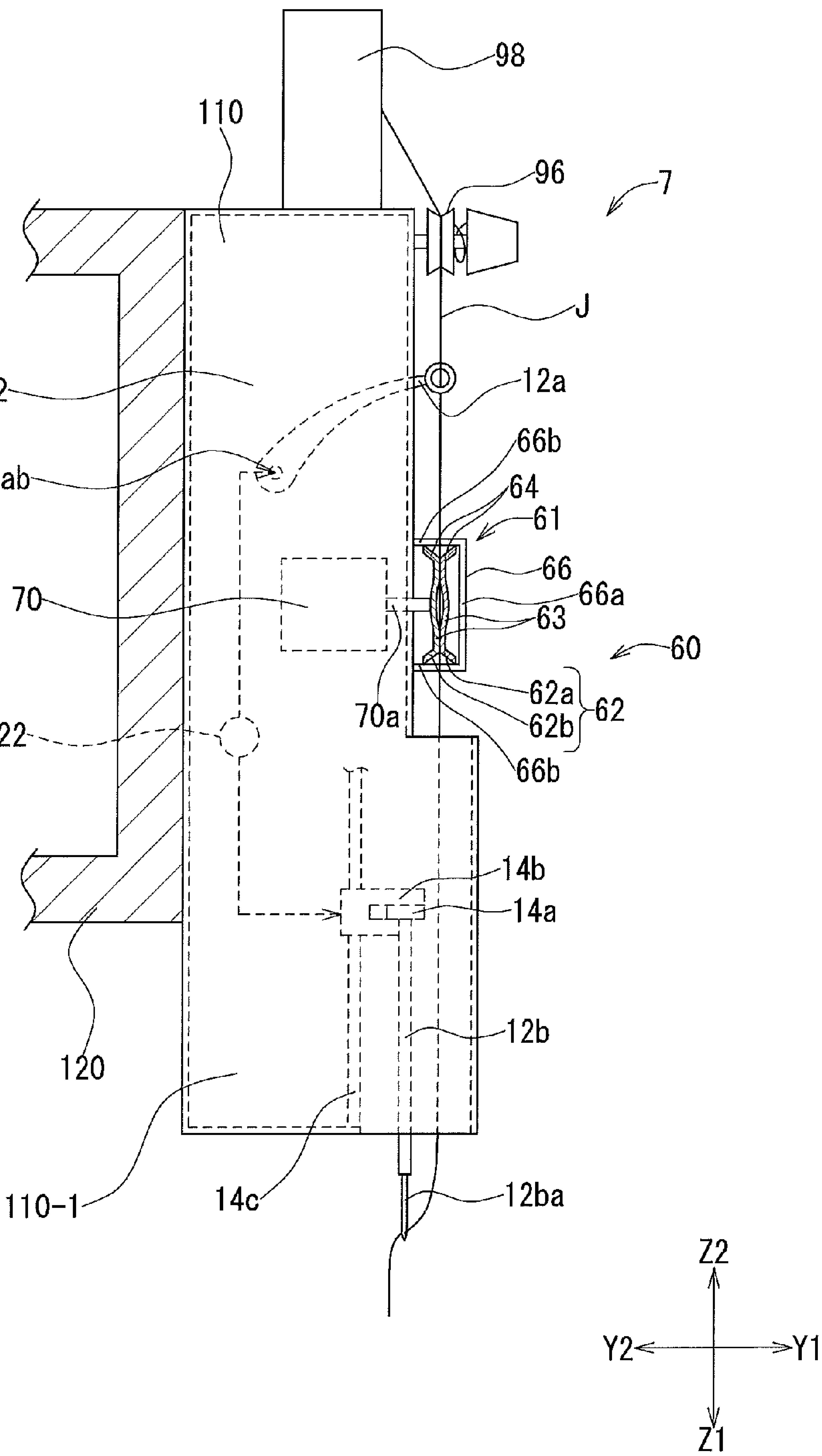

98
110
96
7
J
110-2
12a
66b
12ab
64
61
66
66a
70
63
60
70a
62a
62
62b
22
66b
14b
14a
12b
120
110-1
14c
12ba
Z2
Y2
Y1
Z1

FIG. 5

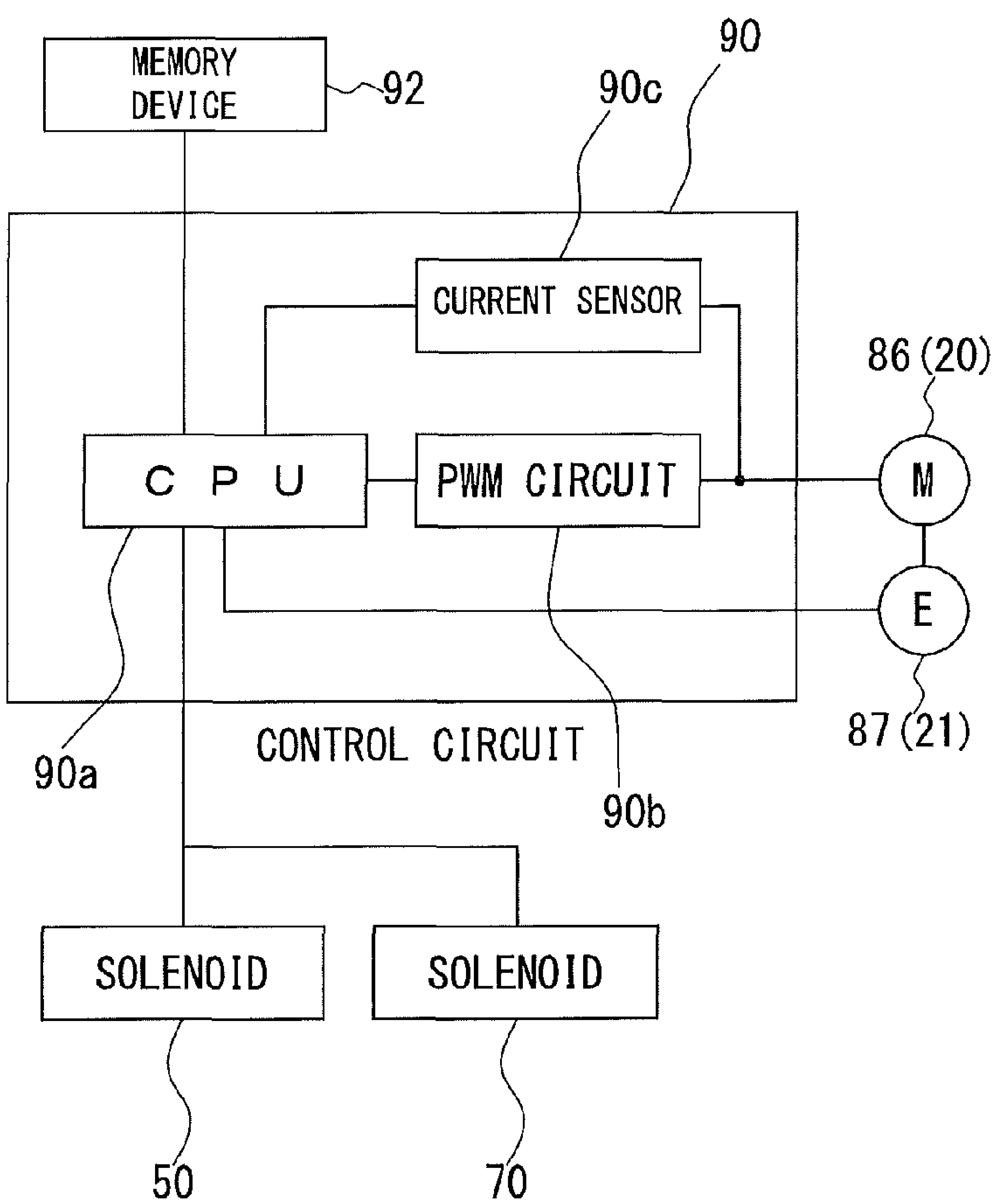

MEMORY DEVICE
92
90c
90
CURRENT SENSOR
86 (20)
C P U
PWM CIRCUIT
M
E
87 (21)
90a
CONTROL CIRCUIT
90b
SOLENOID
SOLENOID
50
70

FIG. 6

ZONE POSITION DATA

	STARTING PIONT	END POINT
TORQUE CONTROL ZONE (MAIN SPINDLE ANGLE)	Z_1 DEGREE	Z_2 DEGREE
POSITION CONTROL ZONE (MAIN SPINDLE ANGLE)	Z_3 DEGREE	Z_4 DEGREE

FIG. 7

MAIN SPINDLE DATA (POSITION)

TIME	MAIN SPINDLE ANGLE
t_0	a_0 (=0)
t_1	a_1
t_2	a_2
.	.
.	.
.	.
.	.
.	.
t_n	a_n

FIG. 8

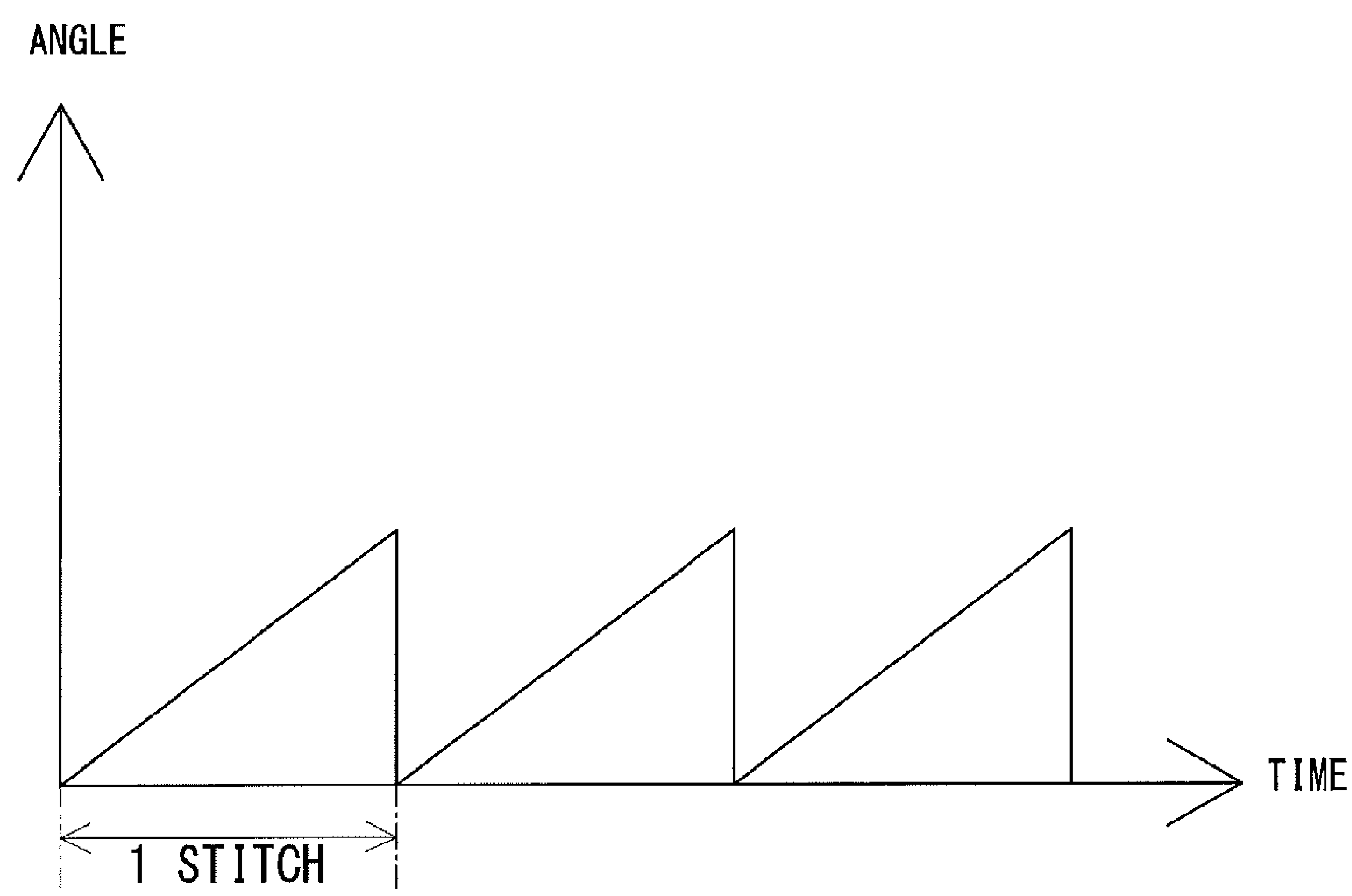


FIG. 9

NEEDLE THREAD CONTROL TORQUE DATA

STITCH	TORQUE VALUE
STITCH 1	b_0
STITCH 2	b_1
.	.
.	.
.	.
.	.
.	.
.	.
STITCH n	b_n

FIG. 10

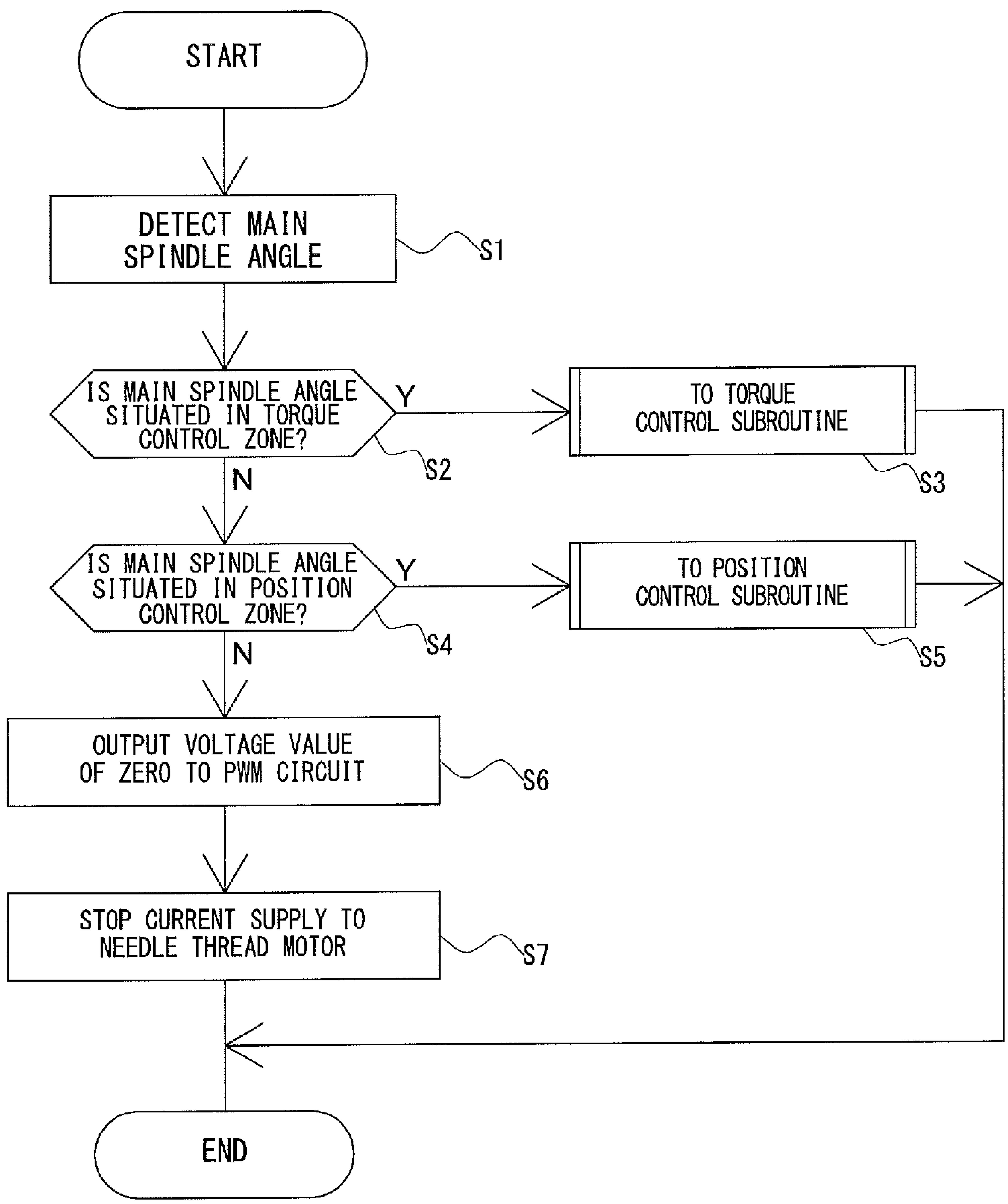

START
DETECT MAIN SPINDLE ANGLE
S1
IS MAIN SPINDLE ANGLE SITUATED IN TORQUE CONTROL ZONE?
Y
N
S2
TO TORQUE CONTROL SUBROUTINE
S3
IS MAIN SPINDLE ANGLE SITUATED IN POSITION CONTROL ZONE?
Y
N
S4
TO POSITION CONTROL SUBROUTINE
S5
OUTPUT VOLTAGE VALUE OF ZERO TO PWM CIRCUIT
S6
STOP CURRENT SUPPLY TO NEEDLE THREAD MOTOR
S7
END

FIG. 11

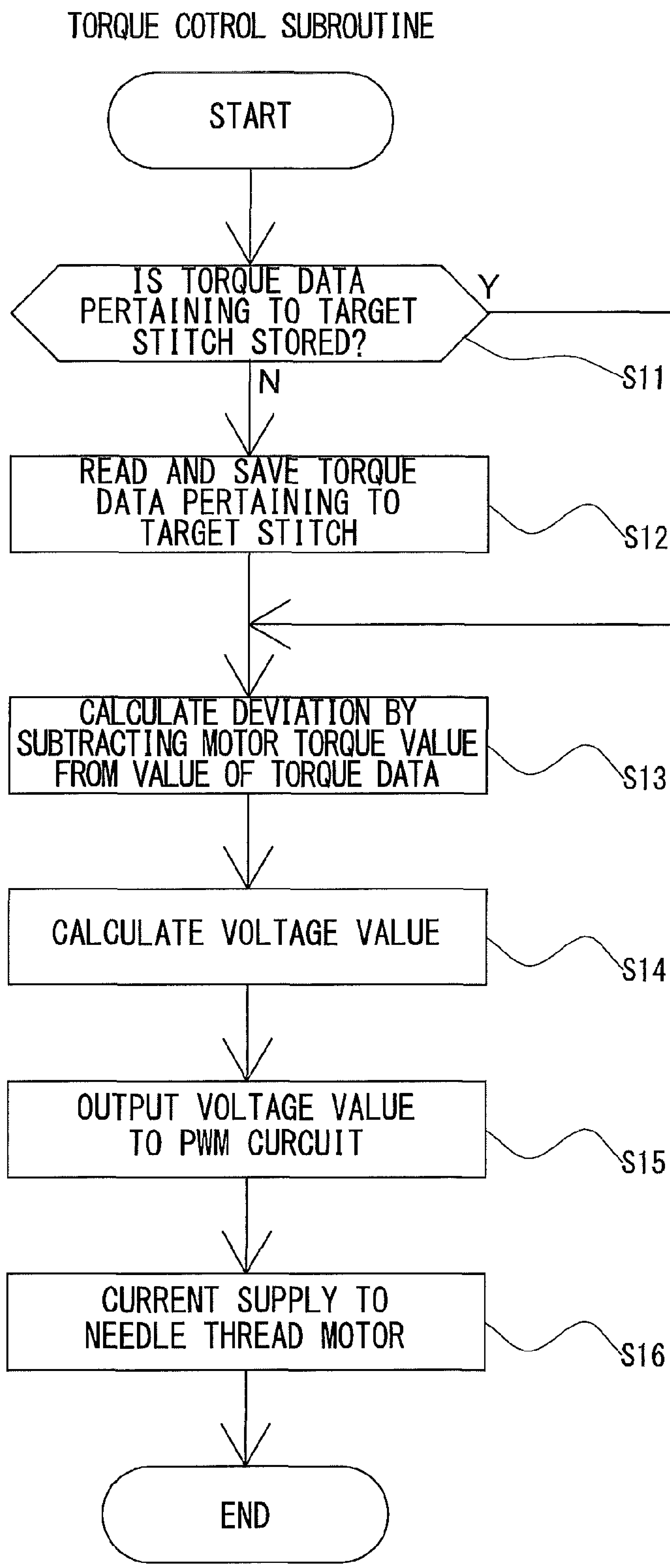

TORQUE COTROL SUBROUTINE
START
IS TORQUE DATA PERTAINING TO TARGET STITCH STORED?
Y
N
S11
READ AND SAVE TORQUE DATA PERTAINING TO TARGET STITCH
S12
CALCULATE DEVIATION BY SUBTRACTING MOTOR TORQUE VALUE FROM VALUE OF TORQUE DATA
S13
CALCULATE VOLTAGE VALUE
S14
OUTPUT VOLTAGE VALUE TO PWM CURCUIT
S15
CURRENT SUPPLY TO NEEDLE THREAD MOTOR
S16
END

FIG. 12

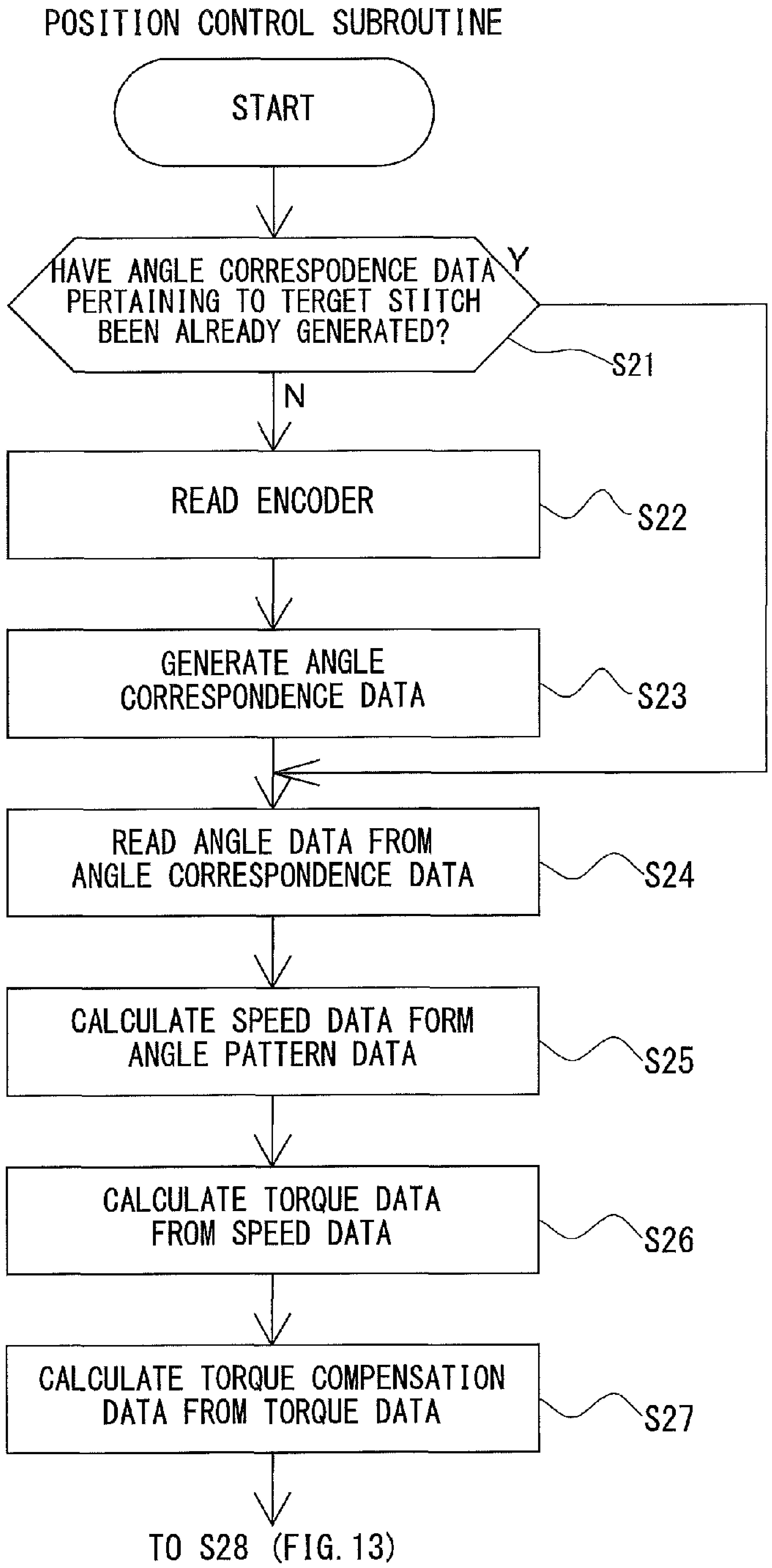

POSITION CONTROL SUBROUTINE
START
HAVE ANGLE CORRESPODENCE DATA PERTAINING TO TERGET STITCH BEEN ALREADY GENERATED?
Y
N
S21
READ ENCODER
S22
GENERATE ANGLE CORRESPONDENCE DATA
S23
READ ANGLE DATA FROM ANGLE CORRESPONDENCE DATA
S24
CALCULATE SPEED DATA FORM ANGLE PATTERN DATA
S25
CALCULATE TORQUE DATA FROM SPEED DATA
S26
CALCULATE TORQUE COMPENSATION DATA FROM TORQUE DATA
S27
TO S28 (FIG. 13)

FIG. 13

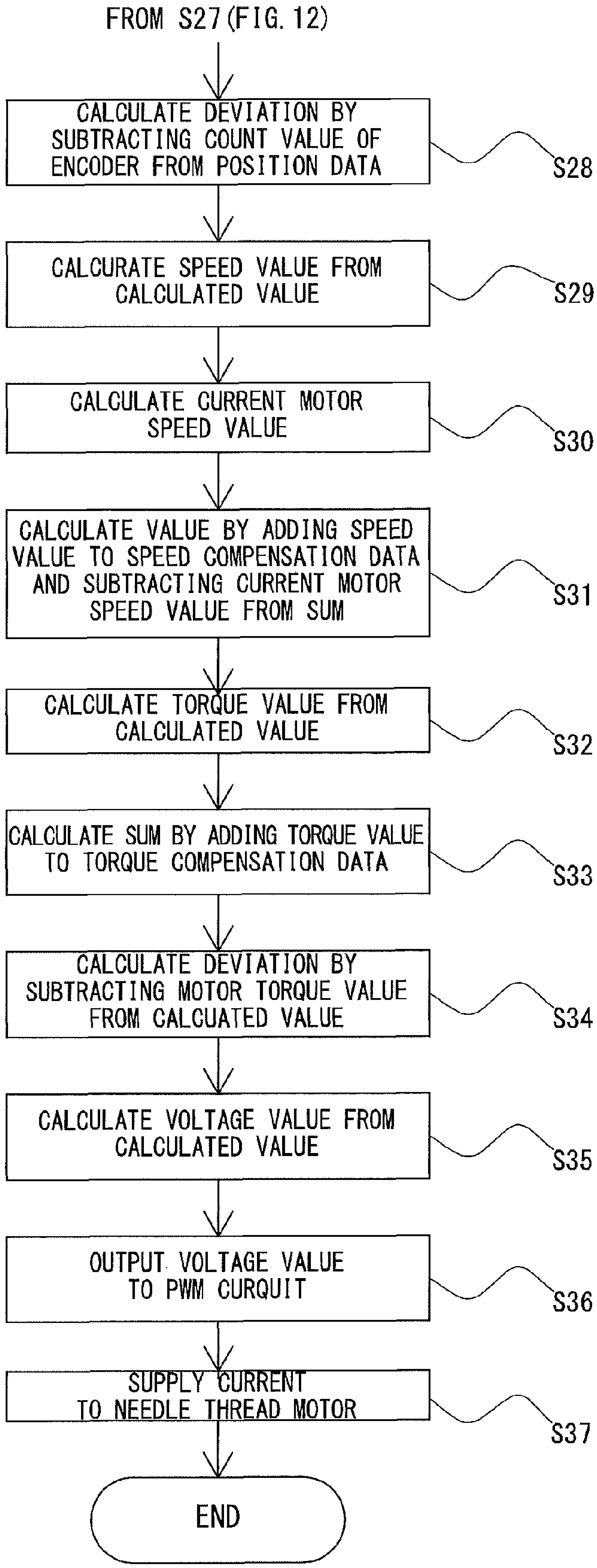
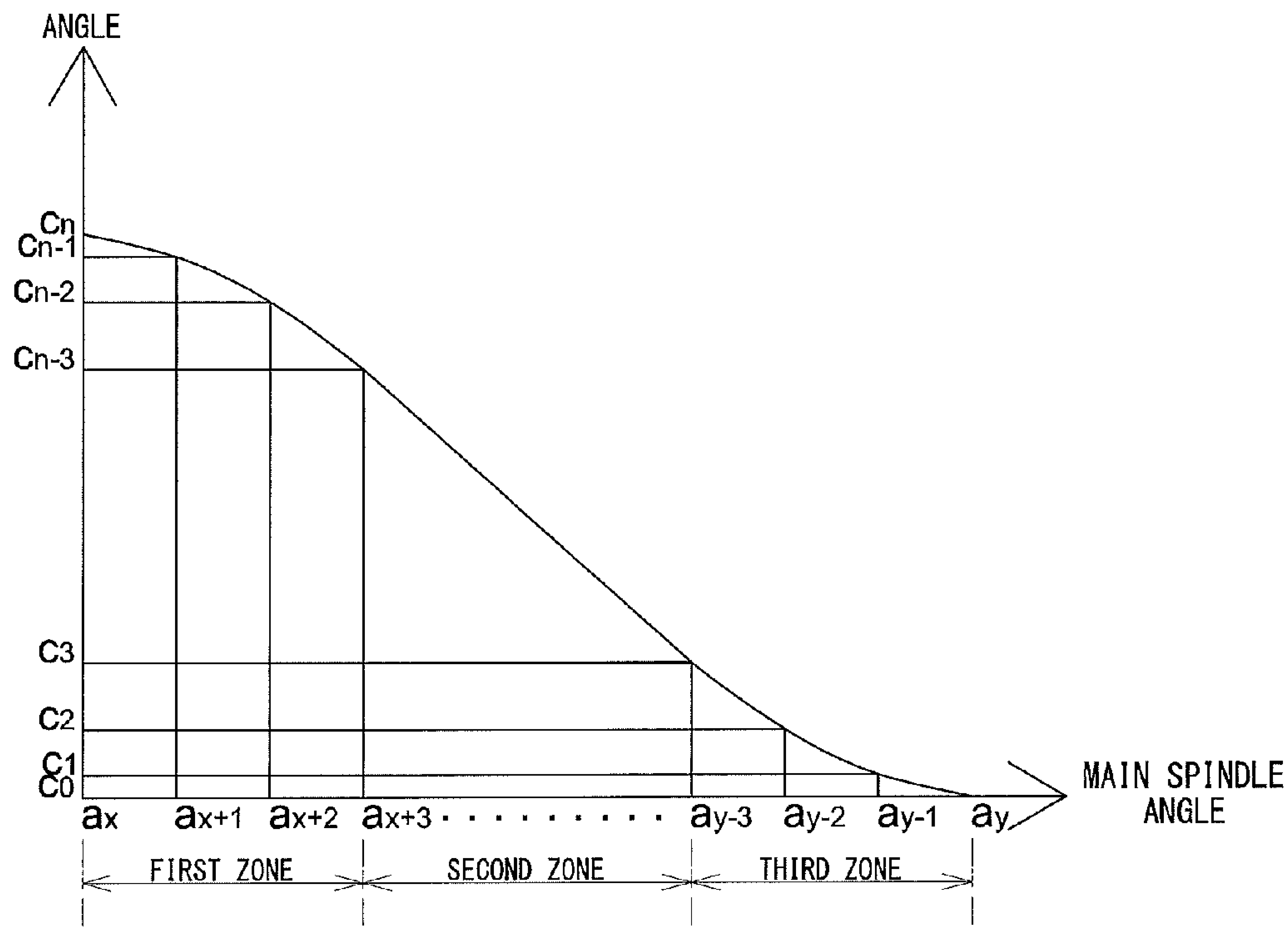

FROM S27 (FIG. 12)
CALCULATE DEVIATION BY SUBTRACTING COUNT VALUE OF ENCODER FROM POSITION DATA
S28
CALCURATE SPEED VALUE FROM CALCULATED VALUE
S29
CALCULATE CURRENT MOTOR SPEED VALUE
S30
CALCULATE VALUE BY ADDING SPEED VALUE TO SPEED COMPENSATION DATA AND SUBTRACTING CURRENT MOTOR SPEED VALUE FROM SUM
S31
CALCULATE TORQUE VALUE FROM CALCULATED VALUE
S32
CALCULATE SUM BY ADDING TORQUE VALUE TO TORQUE COMPENSATION DATA
S33
CALCULATE DEVIATION BY SUBTRACTING MOTOR TORQUE VALUE FROM CALCUATED VALUE
S34
CALCULATE VOLTAGE VALUE FROM CALCULATED VALUE
S35
OUTPUT VOLTAGE VALUE TO PWM CURQUIT
S36
SUPPLY CURRENT TO NEEDLE THREAD MOTOR
S37
END

FIG. 14



ANGLE
Cn
Cn-1
Cn-2
Cn-3
C3
C2
C1
C0
MAIN SPINDLE ANGLE
ax
ax+1
ax+2
ax+3
ay-3
ay-2
ay-1
ay
FIRST ZONE
SECOND ZONE
THIRD ZONE

FIG. 15

ANGLE CORRESPONDENCE DATA

MAIN SPINDLE ANGLE	NEEDLE THREAD MOTOR ANGLE
a_x	C_n
a_{x+1}	C_{n-1}
a_{x+2}	C_{n-2}
a_{x+3}	C_{n-3}
.	.
.	.
.	.
a_{y-3}	C_3
a_{y-2}	C_2
a_{y-1}	C_1
a_y	C_0

FIG. 16

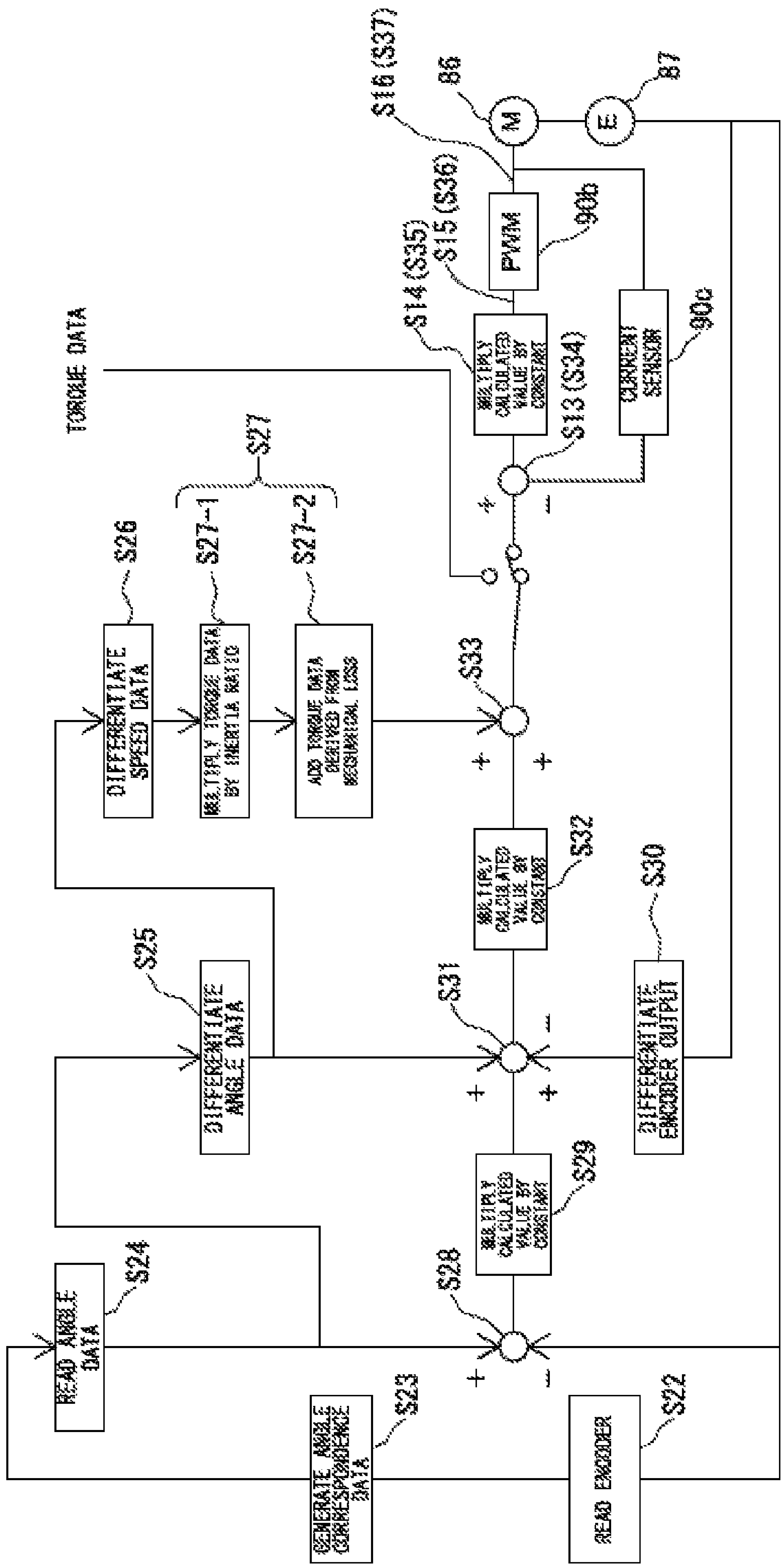

TORQUE DATA
S16 (S37)
86
M
E
87
S15 (S36)
PWM
90b
S14 (S35)
MULTIPLY CALCULATED VALUE BY CONSTANT
S13 (S34)
CURRENT SENSOR
90c
S27
S27-1
S27-2
S26
DIFFERENTIATE SPEED DATA
MULTIPLY TORQUE DATA BY INERTIA RATIO
ADD TORQUE DATA DERIVED FROM MECHANICAL LOSS
S33
S32
MULTIPLY CALCULATED VALUE BY CONSTANT
S30
DIFFERENTIATE ENCODER OUTPUT
S31
S25
DIFFERENTIATE ANGLE DATA
S29
MULTIPLY CALCULATED VALUE BY CONSTANT
S28
S24
READ ANGLE DATA
S23
GENERATE ANGLE CORRESPONDENCE DATA
S22
READ ENCODER

FIG. 17

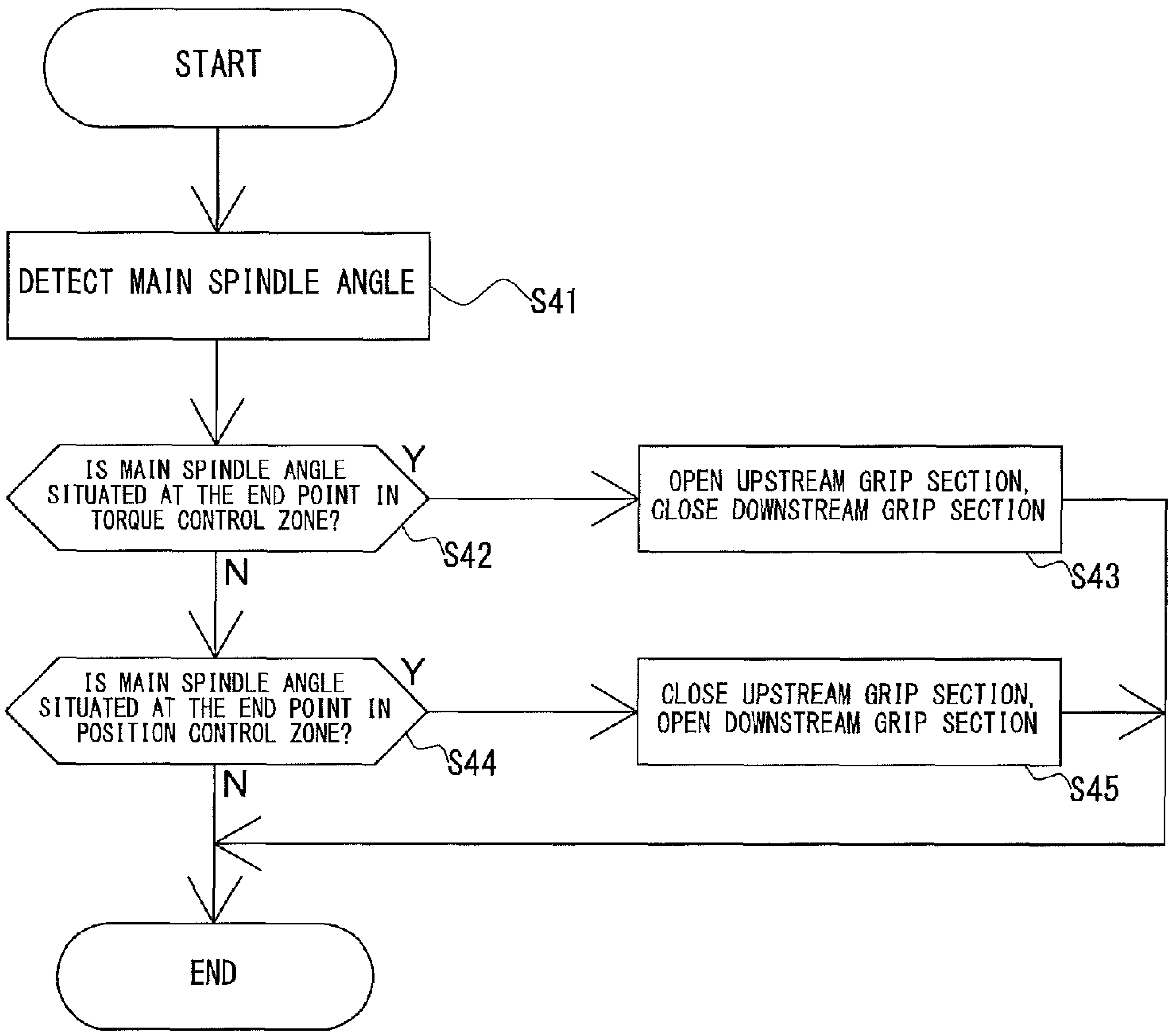
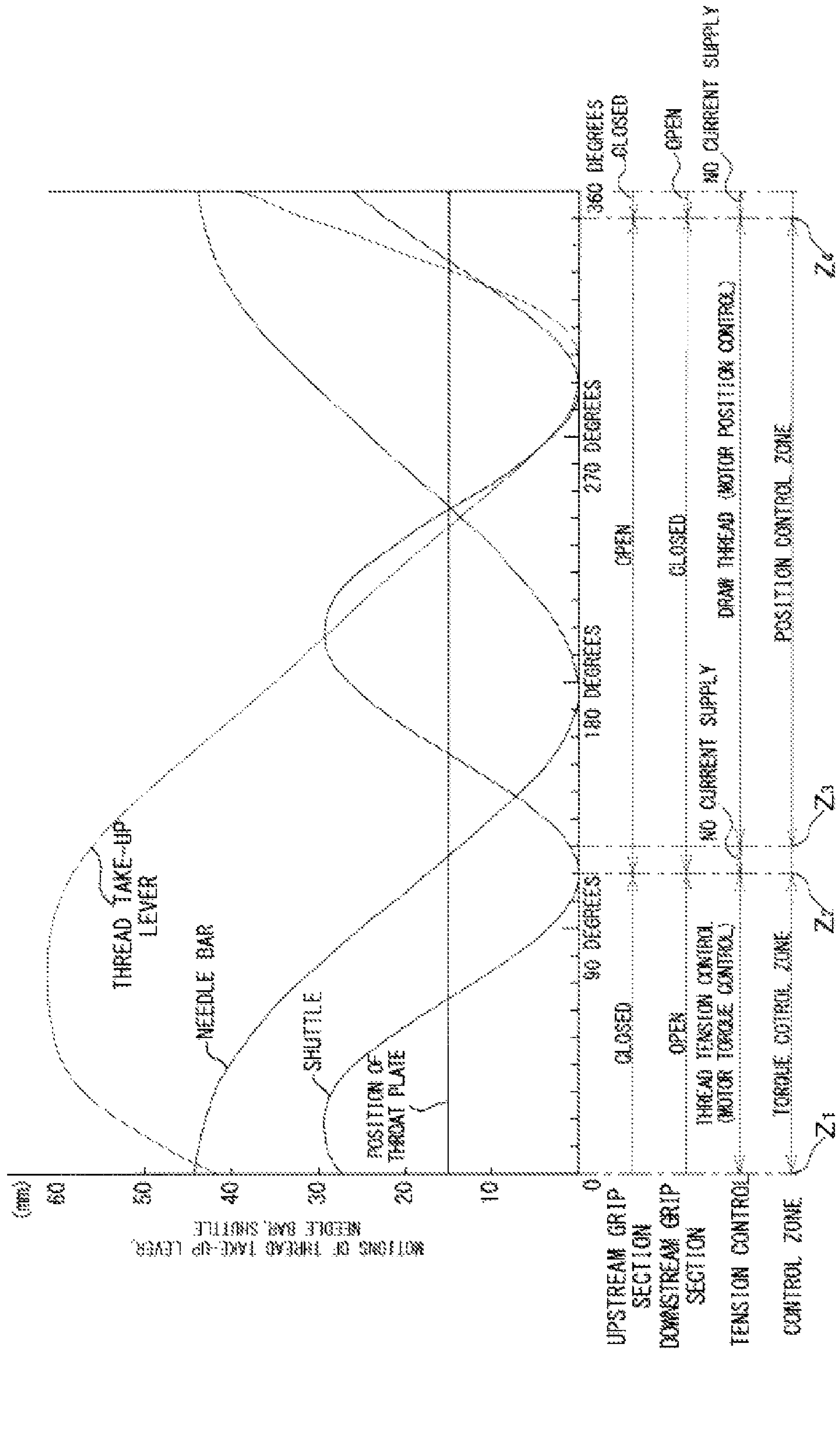

START
DETECT MAIN SPINDLE ANGLE
S41
IS MAIN SPINDLE ANGLE SITUATED AT THE END POINT IN TORQUE CONTROL ZONE?
Y
N
S42
OPEN UPSTREAM GRIP SECTION, CLOSE DOWNSTREAM GRIP SECTION
S43
IS MAIN SPINDLE ANGLE SITUATED AT THE END POINT IN POSITION CONTROL ZONE?
Y
N
S44
CLOSE UPSTREAM GRIP SECTION, OPEN DOWNSTREAM GRIP SECTION
S45
END

FIG. 18



MOTIONS OF THREAD TAKE-UP LEVER, NEEDLE BAR, SHUTTLE
(mm)
60
50
40
30
20
10
0
THREAD TAKE-UP LEVER
NEEDLE BAR
SHUTTLE
POSITION OF THROAT PLATE
90 DEGREES
180 DEGREES
270 DEGREES
360 DEGREES
UPSTREAM GRIP SECTION
DOWNSTREAM GRIP SECTION
TENSION CONTROL
CONTROL ZONE
CLOSED
OPEN
THREAD TENSION CONTROL (MOTOR TORQUE CONTROL)
TORQUE COTROL ZONE
NO CURRENT SUPPLY
OPEN
CLOSED
DRAW THREAD (MOTOR POSITION CONTROL)
POSITION CONTROL ZONE
CLOSED
OPEN
NO CURRENT SUPPLY
Z1
Z2
Z3
Z4

FIG. 19

(a)

(b)

(c)

(d)

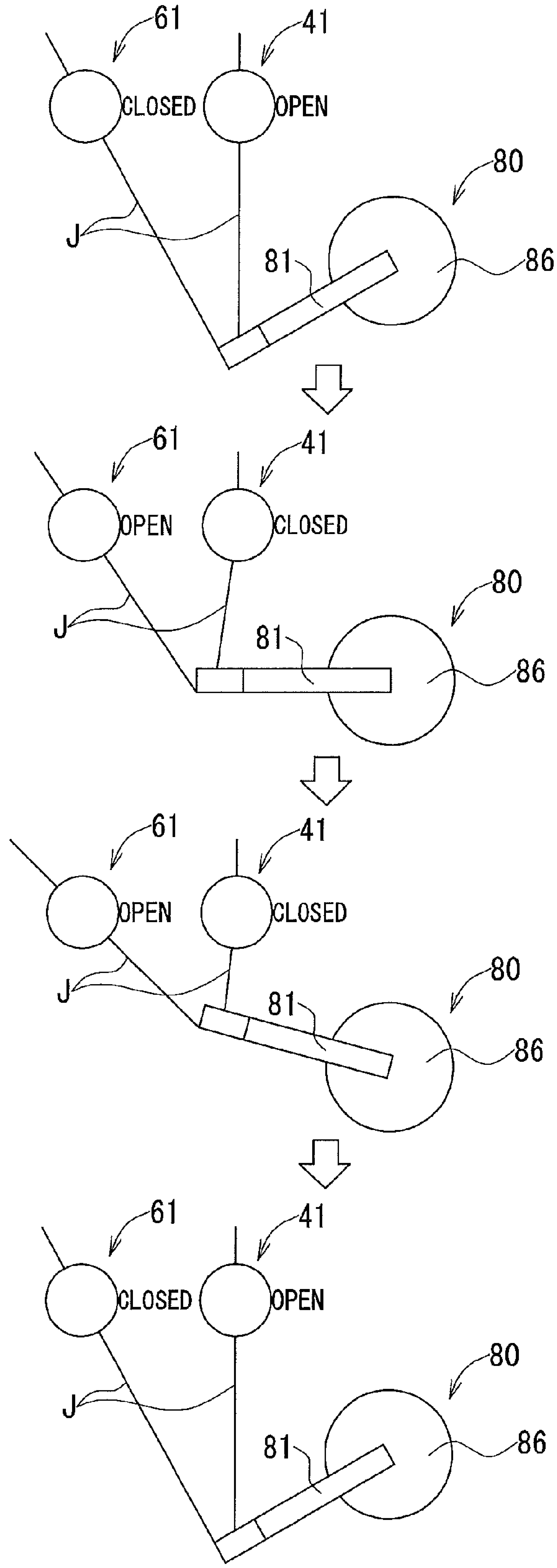

61
41
CLOSED
OPEN
80
J
81
86
61
41
OPEN
CLOSED
80
J
81
86
61
41
OPEN
CLOSED
80
J
81
86
61
41
CLOSED
OPEN
80
J
81
86

FIG. 20

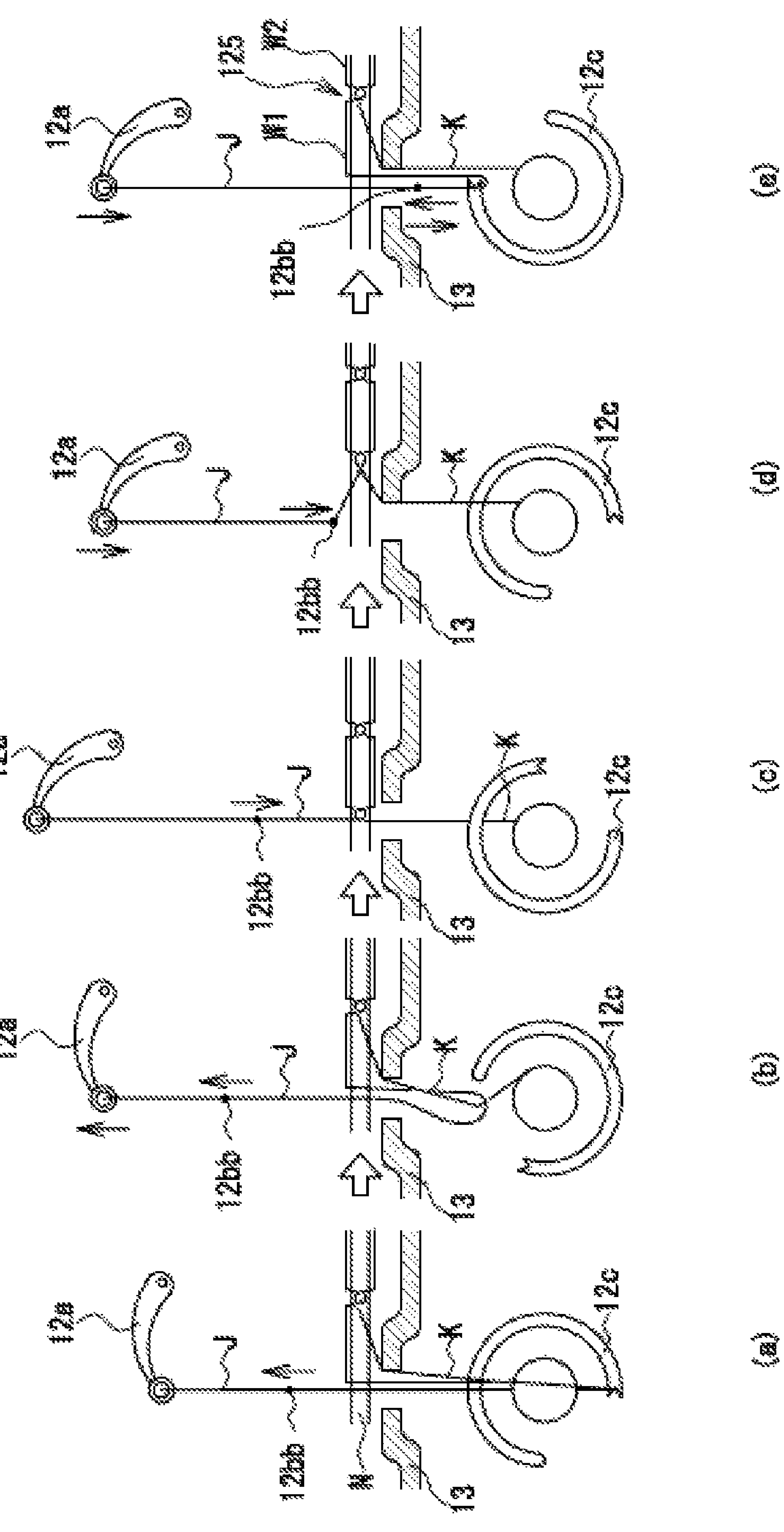


FIG. 21

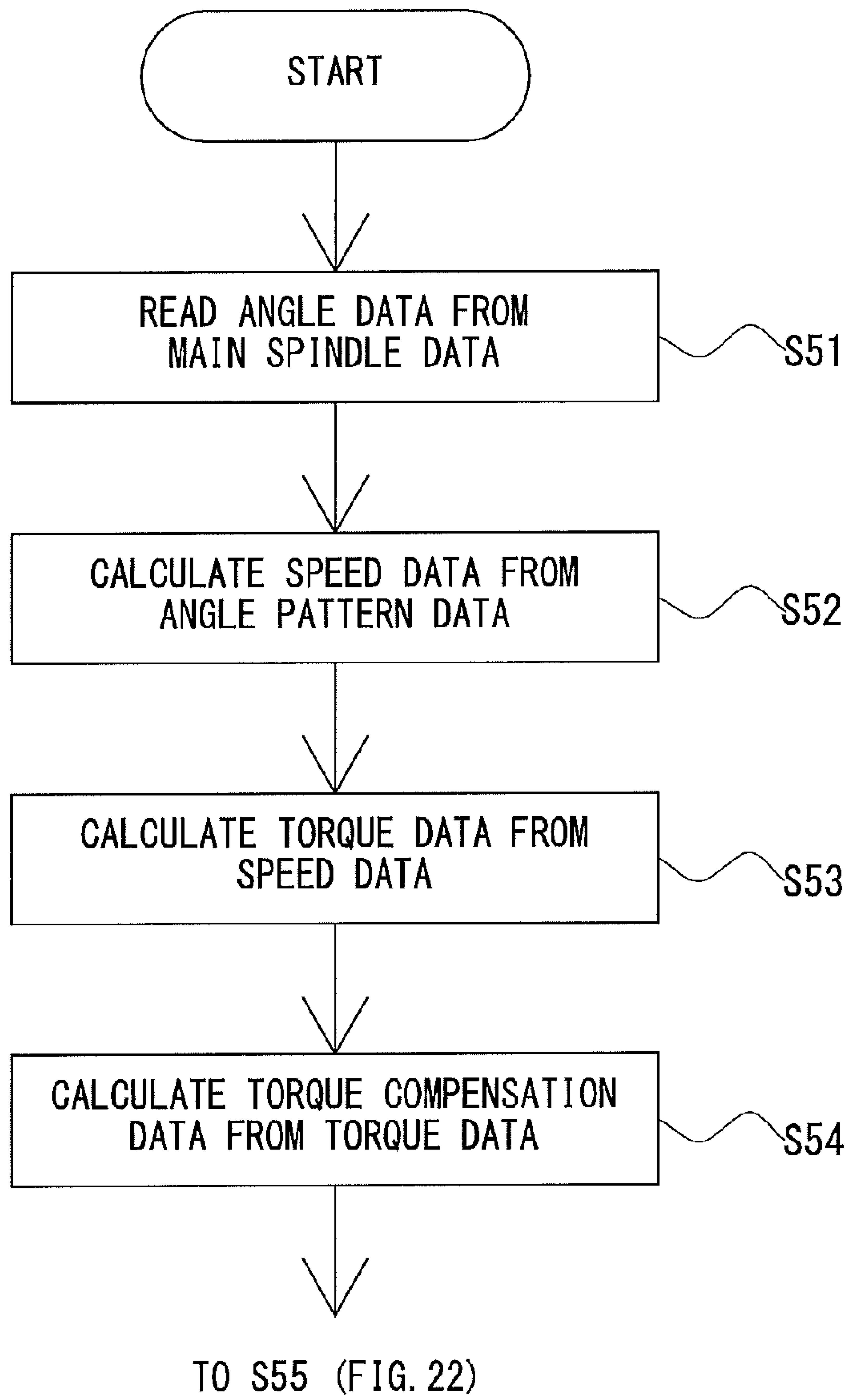

START
READ ANGLE DATA FROM MAIN SPINDLE DATA
S51
CALCULATE SPEED DATA FROM ANGLE PATTERN DATA
S52
CALCULATE TORQUE DATA FROM SPEED DATA
S53
CALCULATE TORQUE COMPENSATION DATA FROM TORQUE DATA
S54
TO S55 (FIG. 22)

FIG. 22

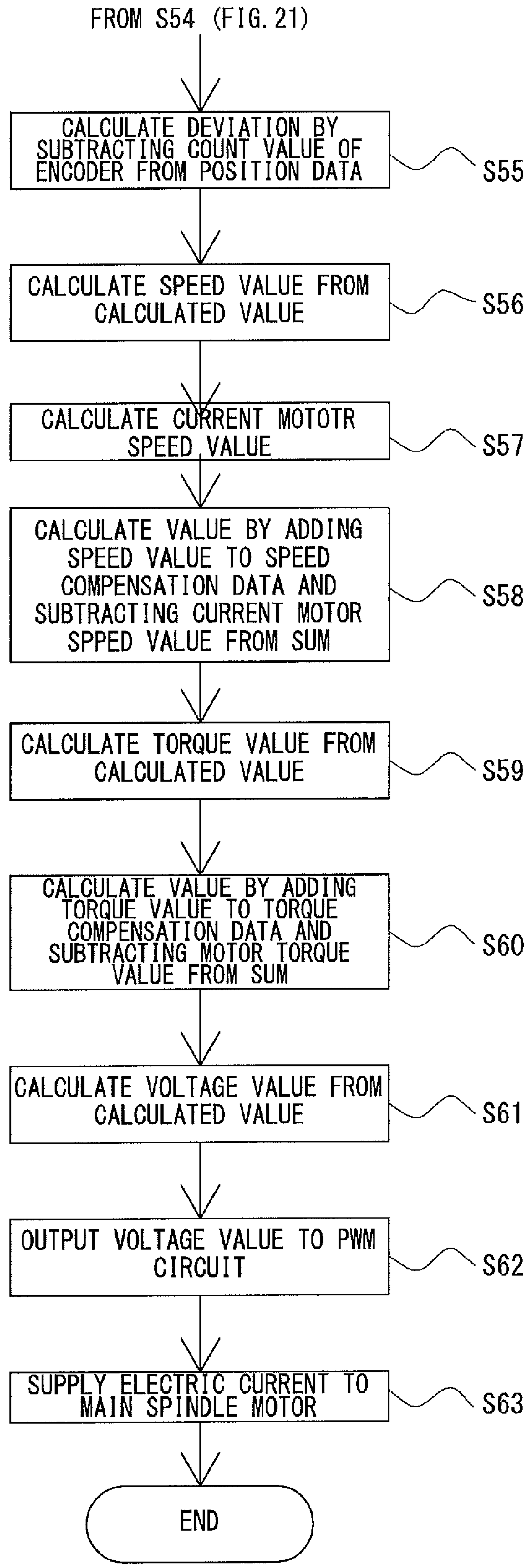

FROM S54 (FIG. 21)
CALCULATE DEVIATION BY SUBTRACTING COUNT VALUE OF ENCODER FROM POSITION DATA
S55
CALCULATE SPEED VALUE FROM CALCULATED VALUE
S56
CALCULATE CURRENT MOTOTR SPEED VALUE
S57
CALCULATE VALUE BY ADDING SPEED VALUE TO SPEED COMPENSATION DATA AND SUBTRACTING CURRENT MOTOR SPPED VALUE FROM SUM
S58
CALCULATE TORQUE VALUE FROM CALCULATED VALUE
S59
CALCULATE VALUE BY ADDING TORQUE VALUE TO TORQUE COMPENSATION DATA AND SUBTRACTING MOTOR TORQUE VALUE FROM SUM
S60
CALCULATE VOLTAGE VALUE FROM CALCULATED VALUE
S61
OUTPUT VOLTAGE VALUE TO PWM CIRCUIT
S62
SUPPLY ELECTRIC CURRENT TO MAIN SPINDLE MOTOR
S63
END

FIG. 23

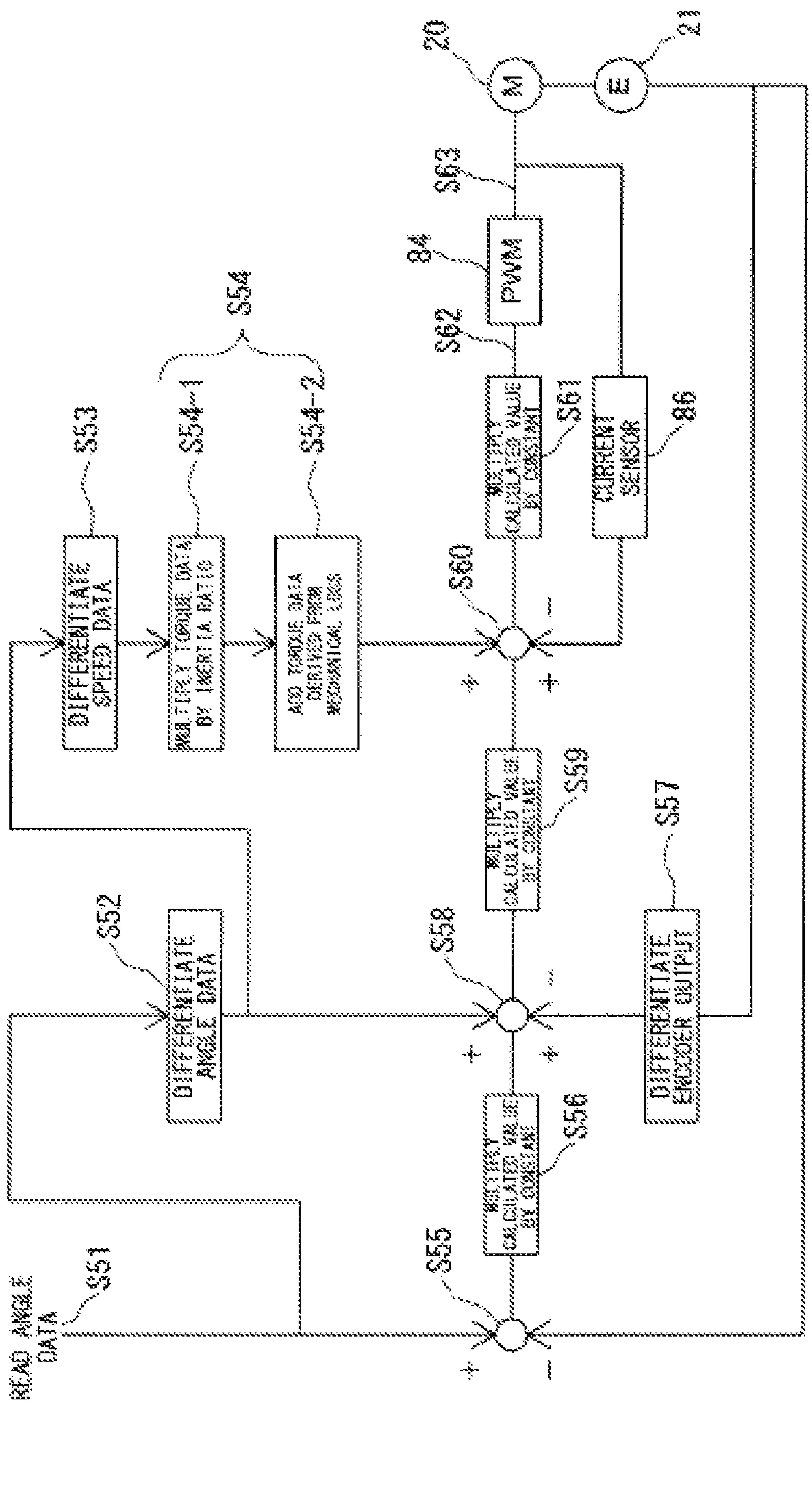

READ ANGLE DATA
S51
S52
DIFFERENTIATE ANGLE DATA
S53
DIFFERENTIATE SPEED DATA
S54
S54-1
MULTIPLY TORQUE DATA BY INERTIA RATIO
S54-2
ADD TORQUE DATA DERIVED FROM MECHANICAL LOSS
S55
S56
MULTIPLY CALCULATED VALUE BY CONSTANT
S57
DIFFERENTIATE ENCODER OUTPUT
S58
S59
MULTIPLY CALCULATED VALUE BY CONSTANT
S60
S61
MULTIPLY CALCULATED VALUE BY CONSTANT
S62
84
PWM
S63
86
CURRENT SENSOR
20
M
21
E
+
-

FIG. 24

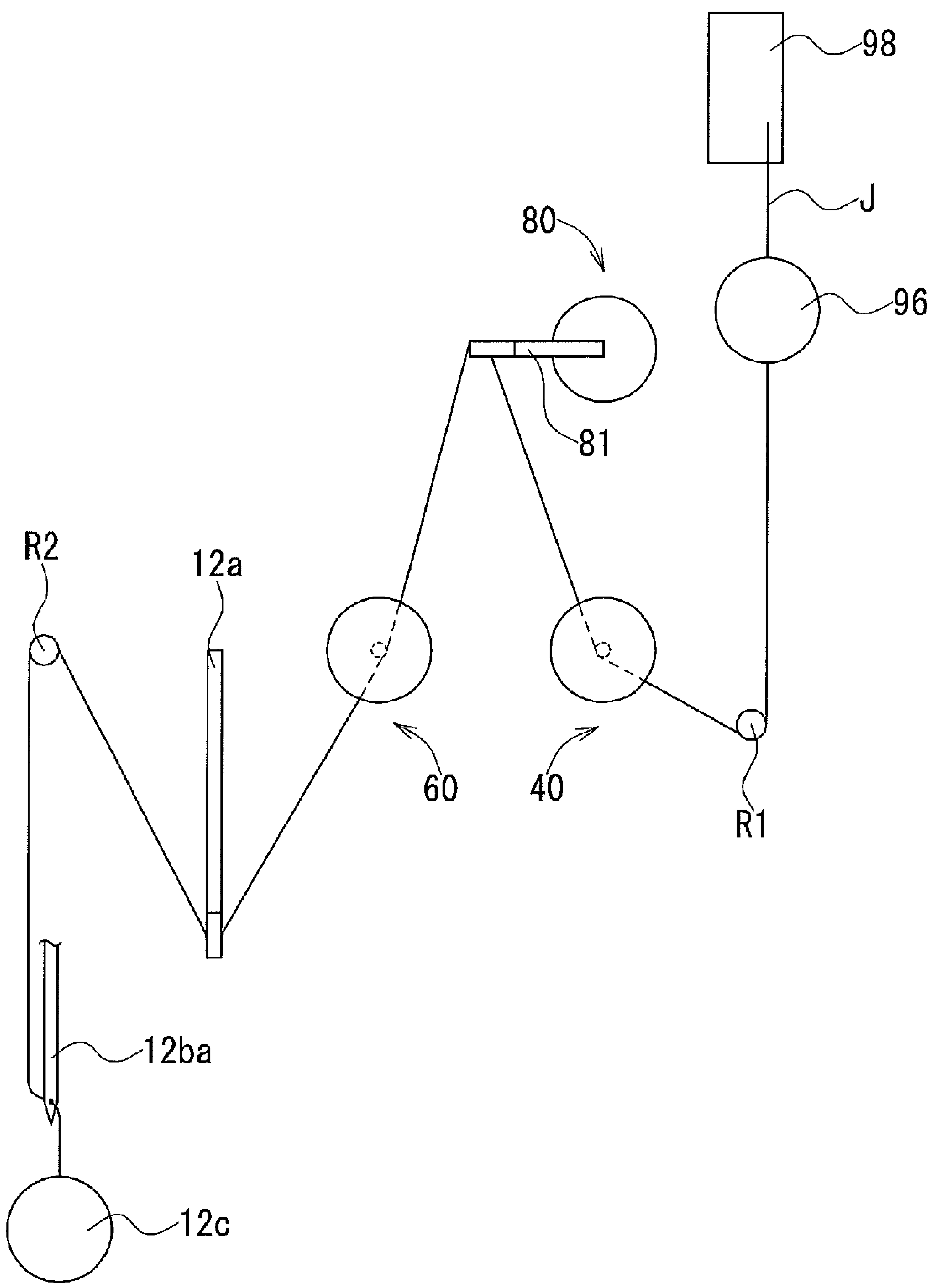
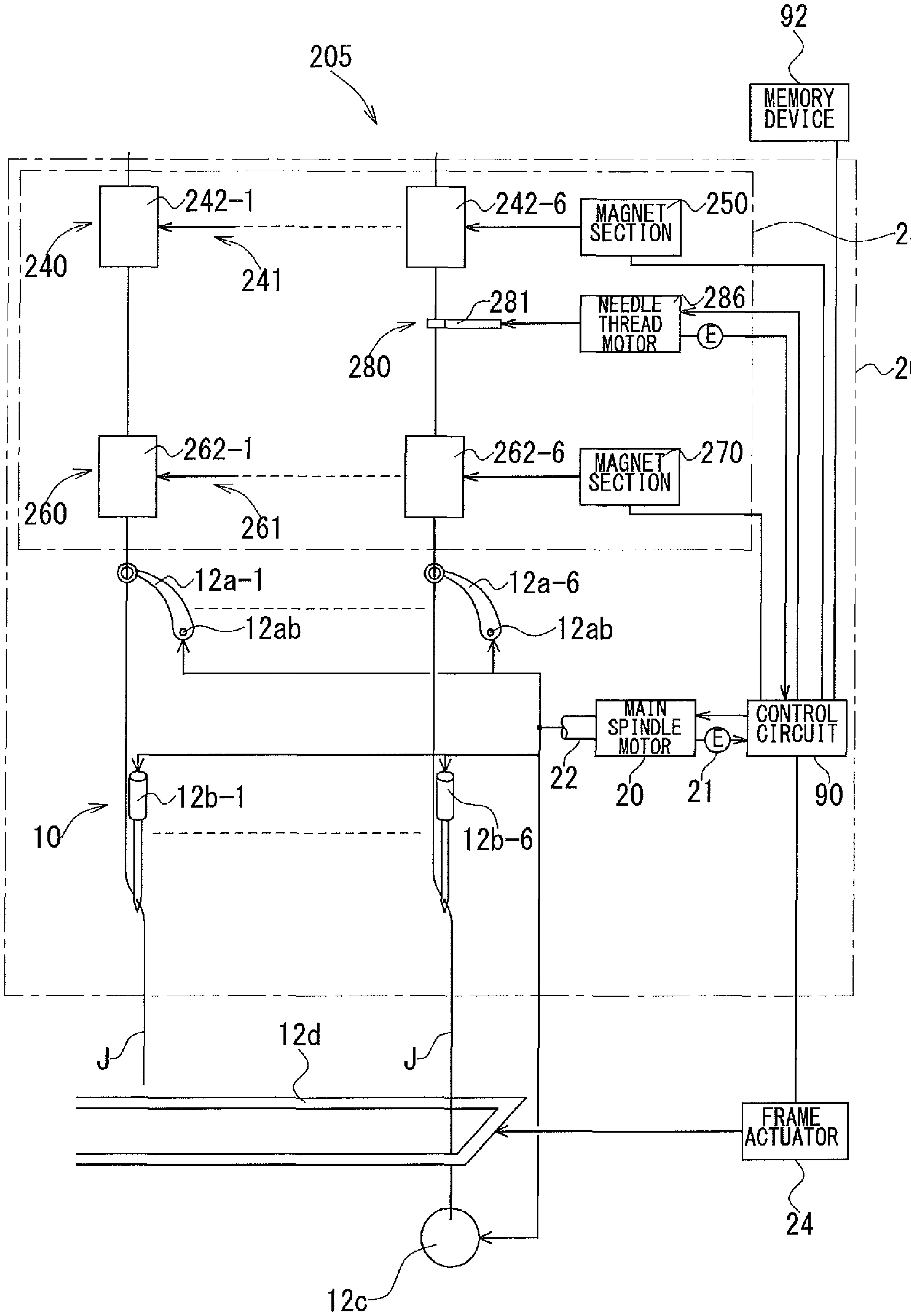
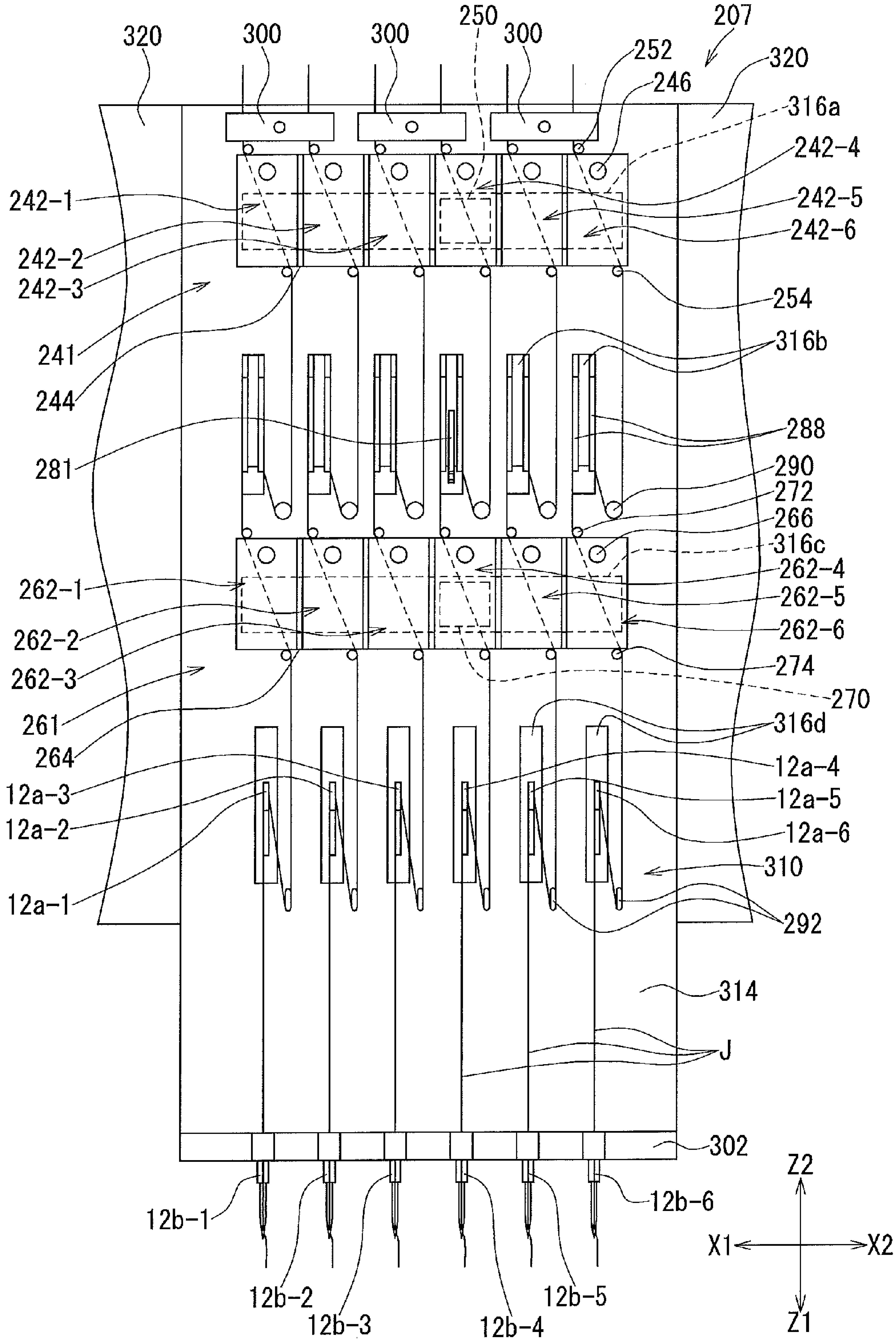


FIG. 25



205
92
MEMORY DEVICE
242-1
242-6
MAGNET SECTION
250
230
240
241
281
NEEDLE THREAD MOTOR
286
E
280
207
262-1
262-6
MAGNET SECTION
270
260
261
12a-1
12a-6
12ab
12ab
MAIN SPINDLE MOTOR
E
CONTROL CIRCUIT
22
20
21
90
12b-1
10
12b-6
J
12d
J
FRAME ACTUATOR
24
12c

FIG. 26



320
300
300
250
300
207
252
246
320
316a
242-4
242-1
242-5
242-6
242-2
242-3
254
241
316b
244
288
281
290
272
266
316c
262-4
262-1
262-5
262-6
262-2
262-3
274
270
261
316d
264
12a-4
12a-3
12a-5
12a-2
12a-6
310
12a-1
292
314
J
302
Z2
12b-6
12b-1
X1
X2
12b-2
12b-5
12b-3
12b-4
Z1

FIG. 27

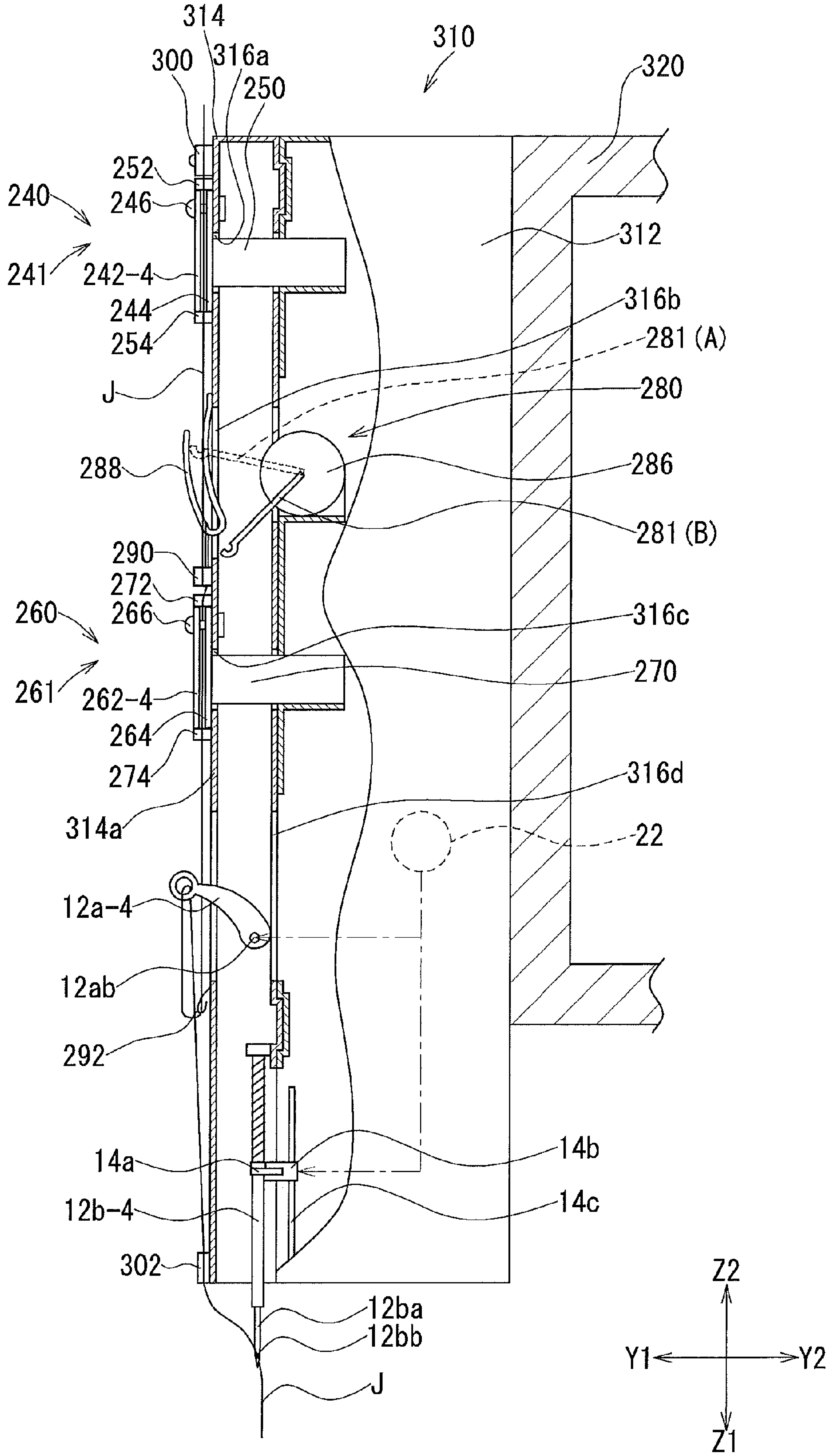

314
316a
300
250
310
320
252
240
246
312
241
242-4
244
254
316b
281 (A)
280
J
288
286
281 (B)
290
272
260
266
316c
270
261
262-4
264
274
316d
314a
22
12a-4
12ab
292
14a
14b
12b-4
14c
302
12ba
12bb
J
Z2
Y1
Y2
Z1

FIG. 28

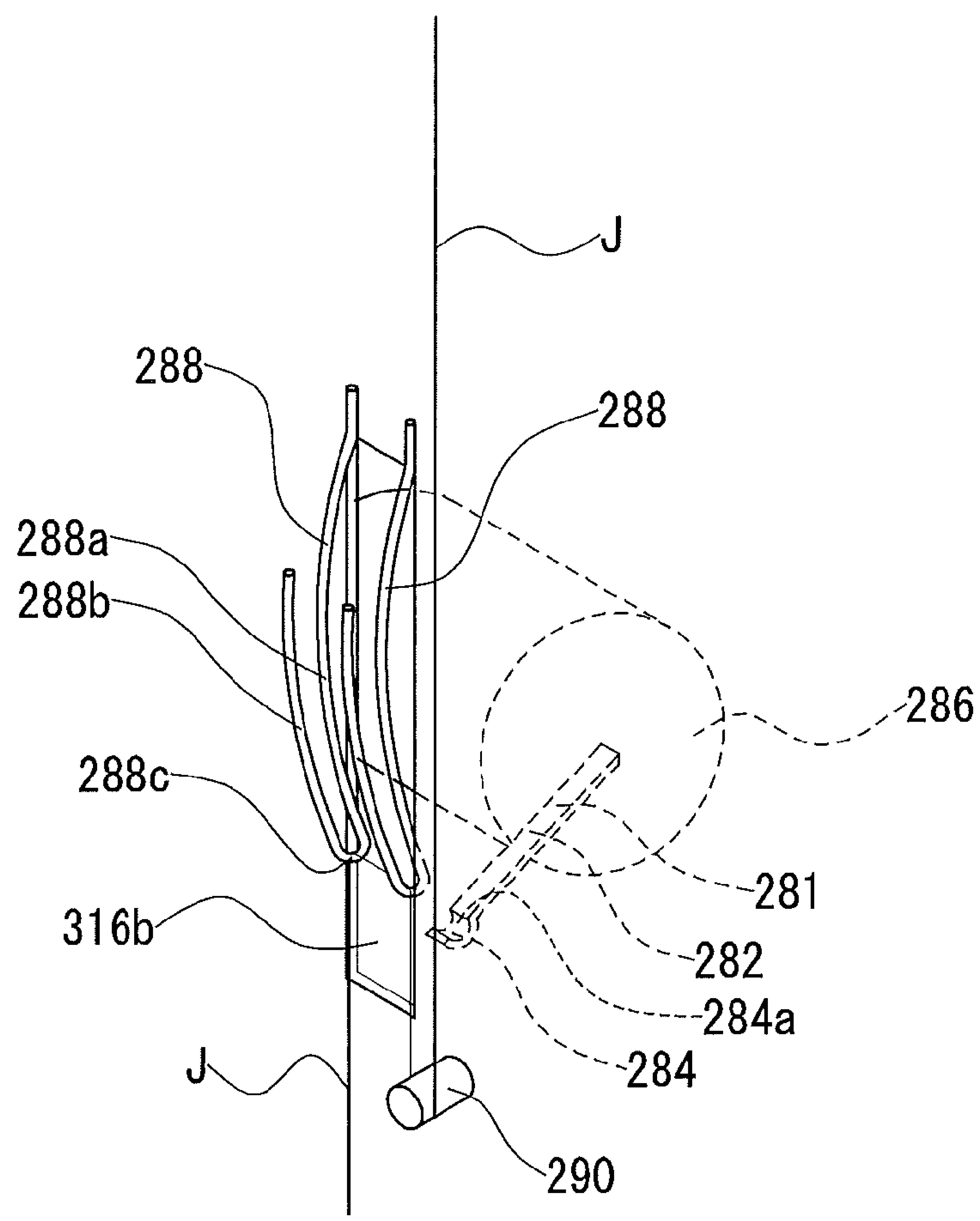
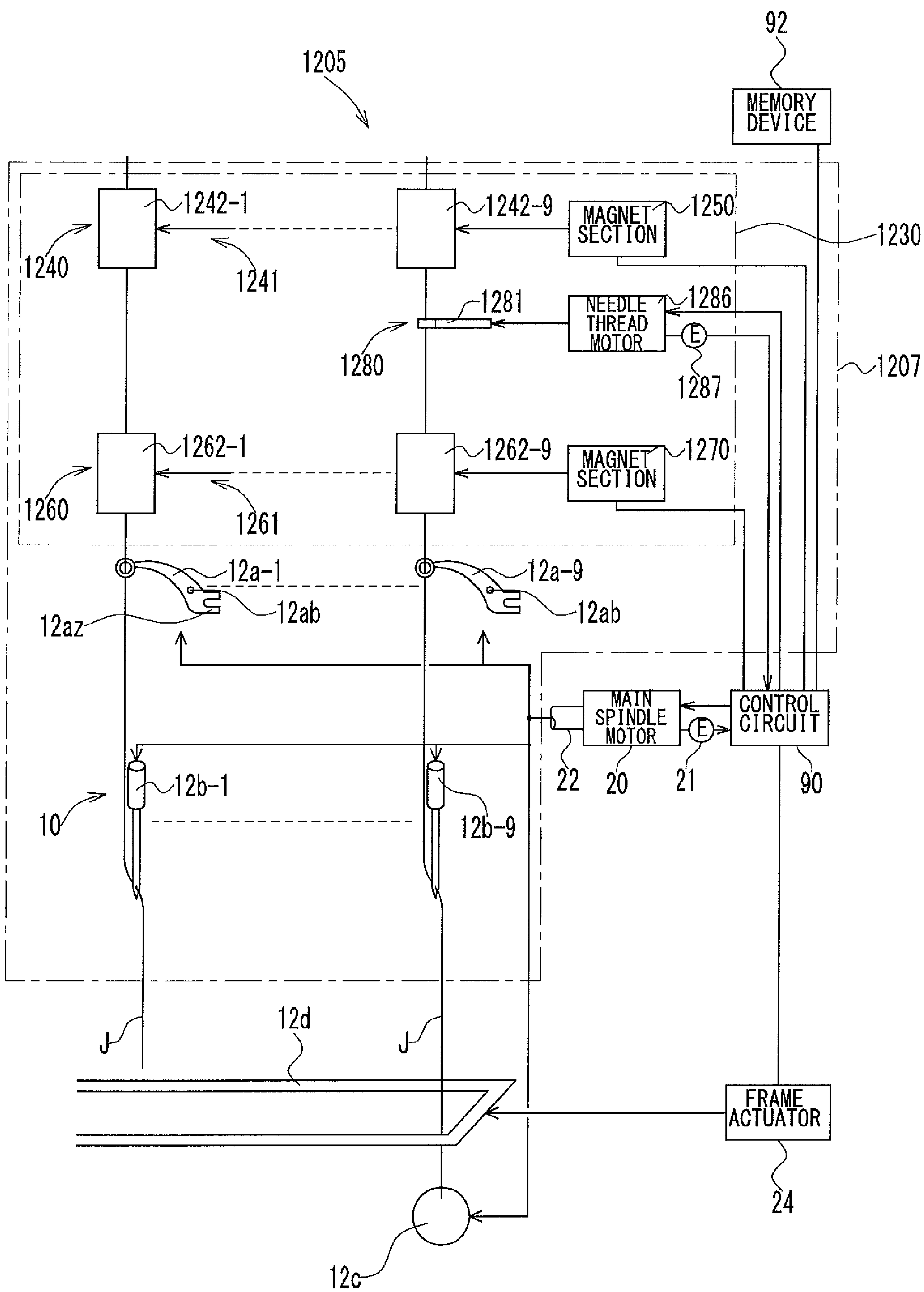
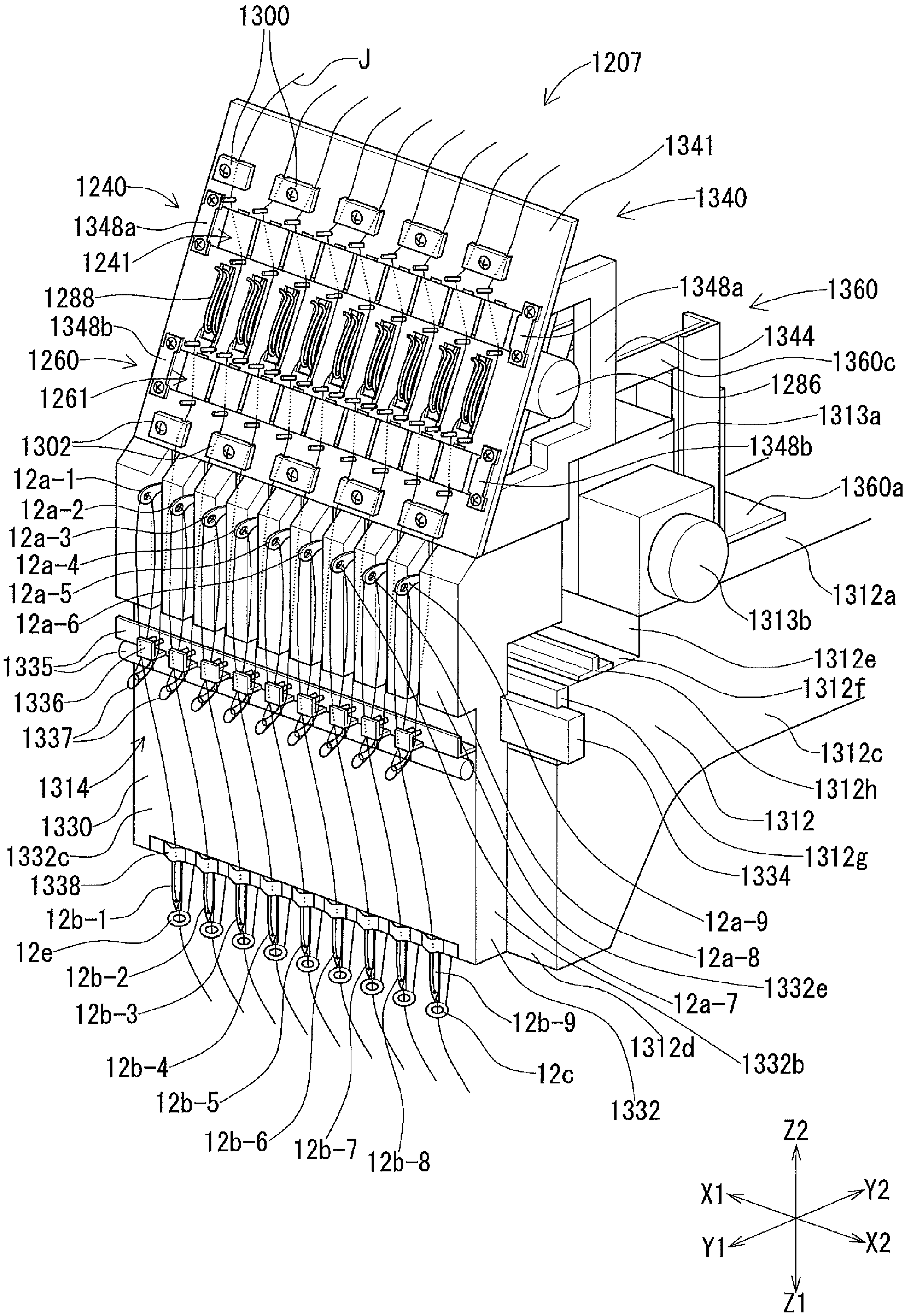


FIG. 29



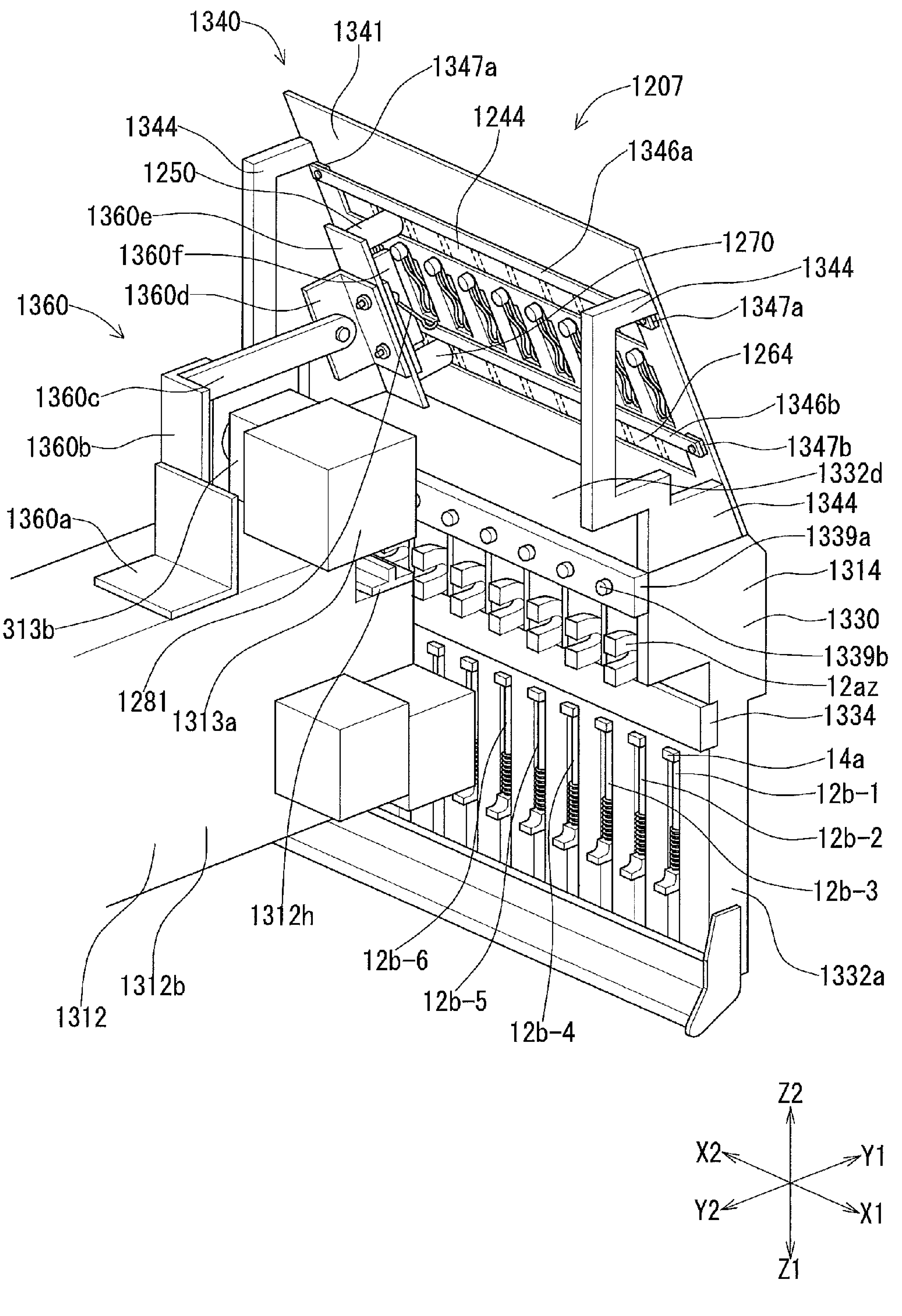
92
MEMORY DEVICE
1205
1242-1
1242-9
MAGNET SECTION
1250
1230
1240
1241
1281
NEEDLE THREAD MOTOR
1286
E
1280
1287
1207
1262-1
1262-9
MAGNET SECTION
1270
1260
1261
12a-1
12a-9
12ab
12ab
12az
MAIN SPINDLE MOTOR
E
CONTROL CIRCUIT
22
20
21
90
12b-1
10
12b-9
J
12d
J
FRAME ACTUATOR
24
12c

FIG. 30



1300
J
1207
1341
1240
1340
1348a
1241
1288
1348a
1360
1348b
1344
1260
1360c
1286
1261
1313a
1302
1348b
12a-1
1360a
12a-2
12a-3
12a-4
12a-5
1312a
12a-6
1313b
1335
1312e
1312f
1336
1337
1312c
1314
1312h
1330
1312
1332c
1312g
1338
1334
12b-1
12a-9
12e
12a-8
12b-2
1332e
12b-3
12a-7
12b-9
1312d
1332b
12b-4
12c
12b-5
1332
12b-6
12b-7
12b-8
Z2
X1
Y2
Y1
X2
Z1

FIG. 31



1340
1341
1347a
1207
1344
1244
1346a
1250
1360e
1270
1360f
1344
1360d
1347a
1360
1264
1360c
1346b
1360b
1347b
1332d
1344
1360a
1339a
1314
1330
1313b
1339b
12az
1281
1313a
1334
14a
12b-1
12b-2
12b-3
1312h
12b-6
1332a
1312b
12b-5
1312
12b-4
Z2
X2
Y1
Y2
X1
Z1

FIG. 32

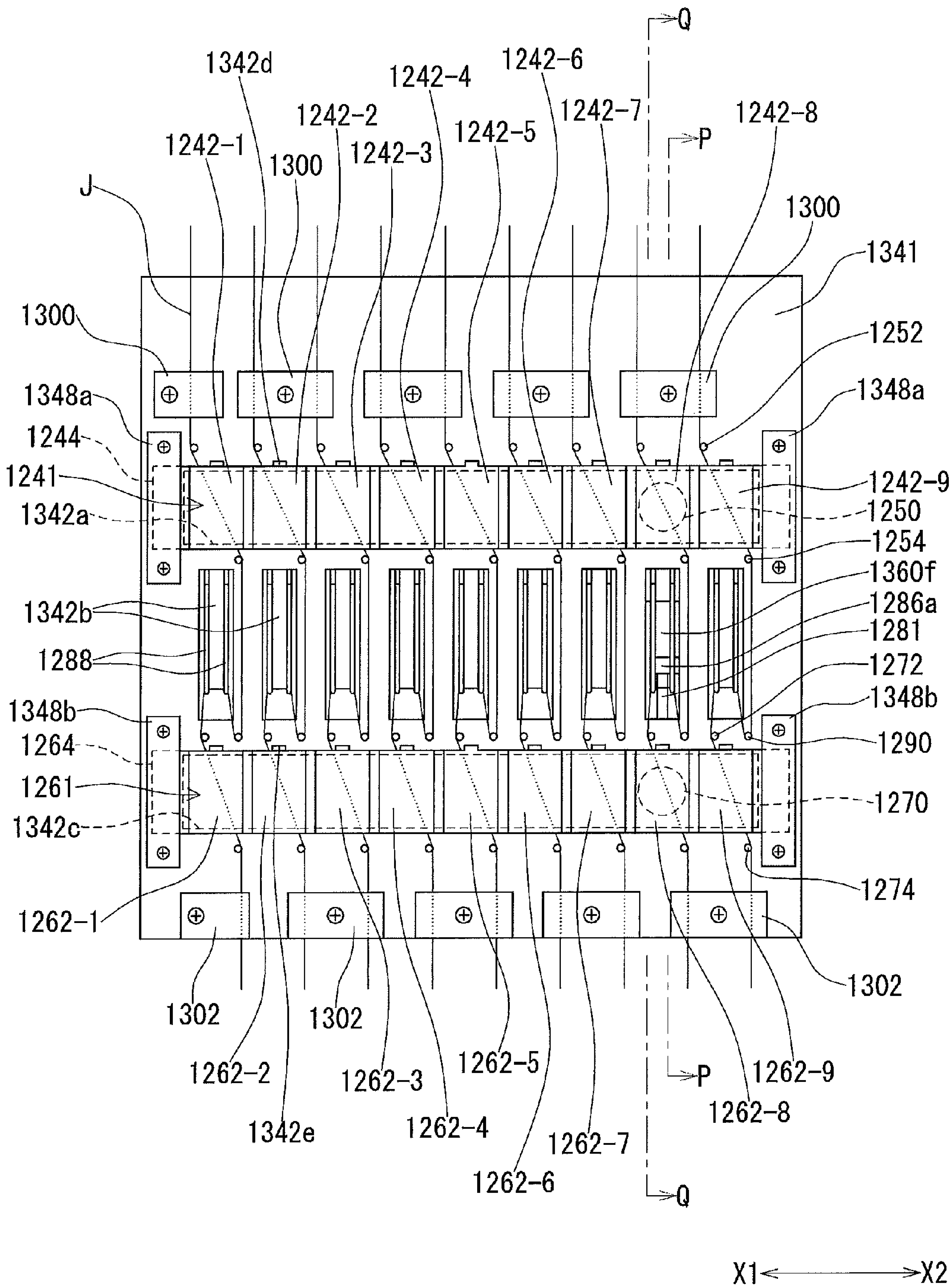

Q
P
1342d
1242-4
1242-6
1242-2
1242-7
1242-8
1242-1
1300
1242-3
1242-5
J
1300
1341
1300
1252
1348a
1348a
1244
1241
1242-9
1342a
1250
1254
1360f
1342b
1286a
1281
1288
1272
1348b
1348b
1264
1290
1261
1270
1342c
1274
1262-1
1302
1302
1302
1262-2
1262-3
1262-5
1262-9
1262-8
1342e
1262-4
1262-7
1262-6
X1
X2

FIG. 33

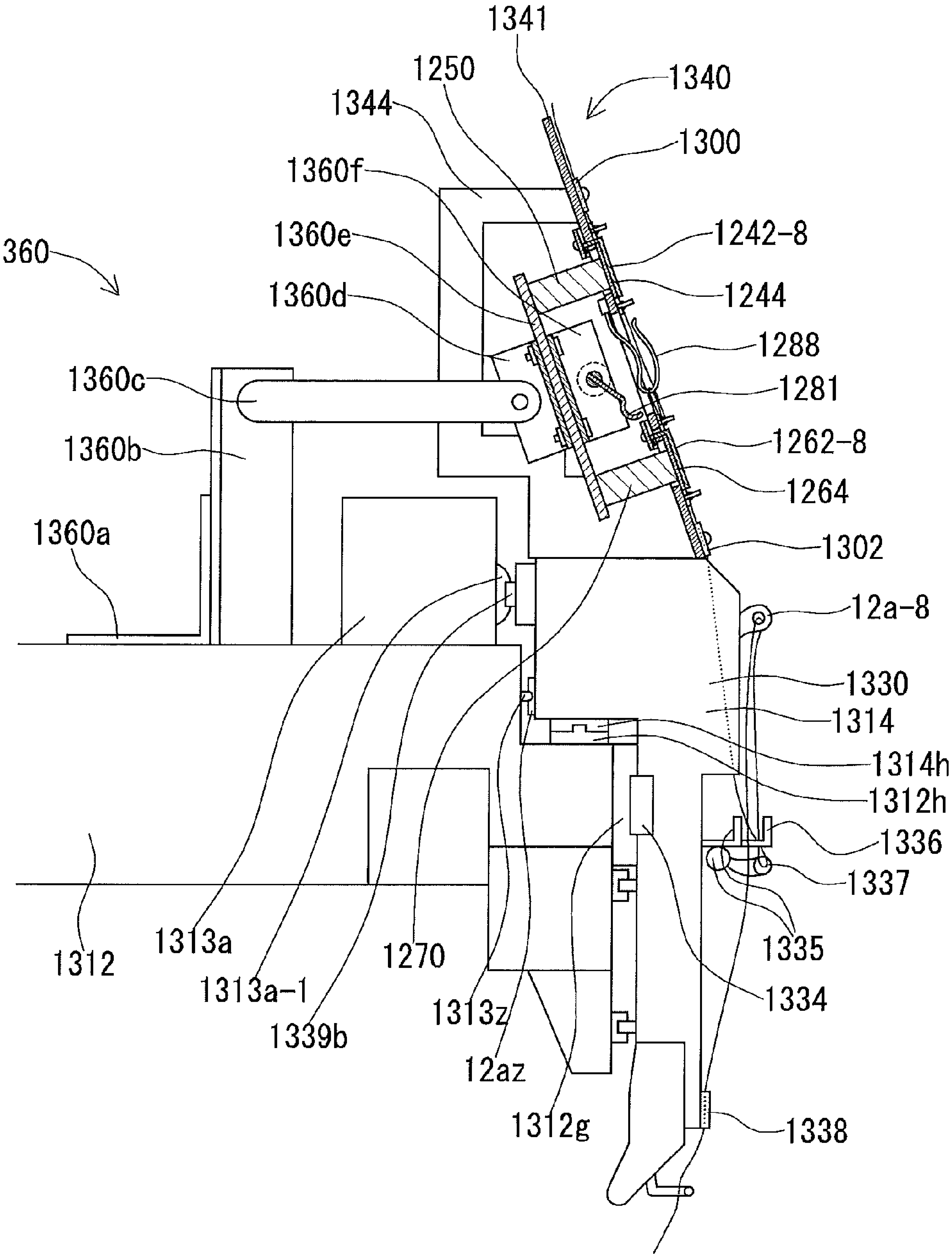

1341
1340
1250
1344
1300
1360f
1242-8
1360e
1360
1244
1360d
1288
1360c
1281
1262-8
1360b
1264
1360a
1302
12a-8
1330
1314
1314h
1312h
1336
1337
1335
1312
1313a
1270
1313a-1
1334
1339b
1313z
12az
1312g
1338

FIG. 34

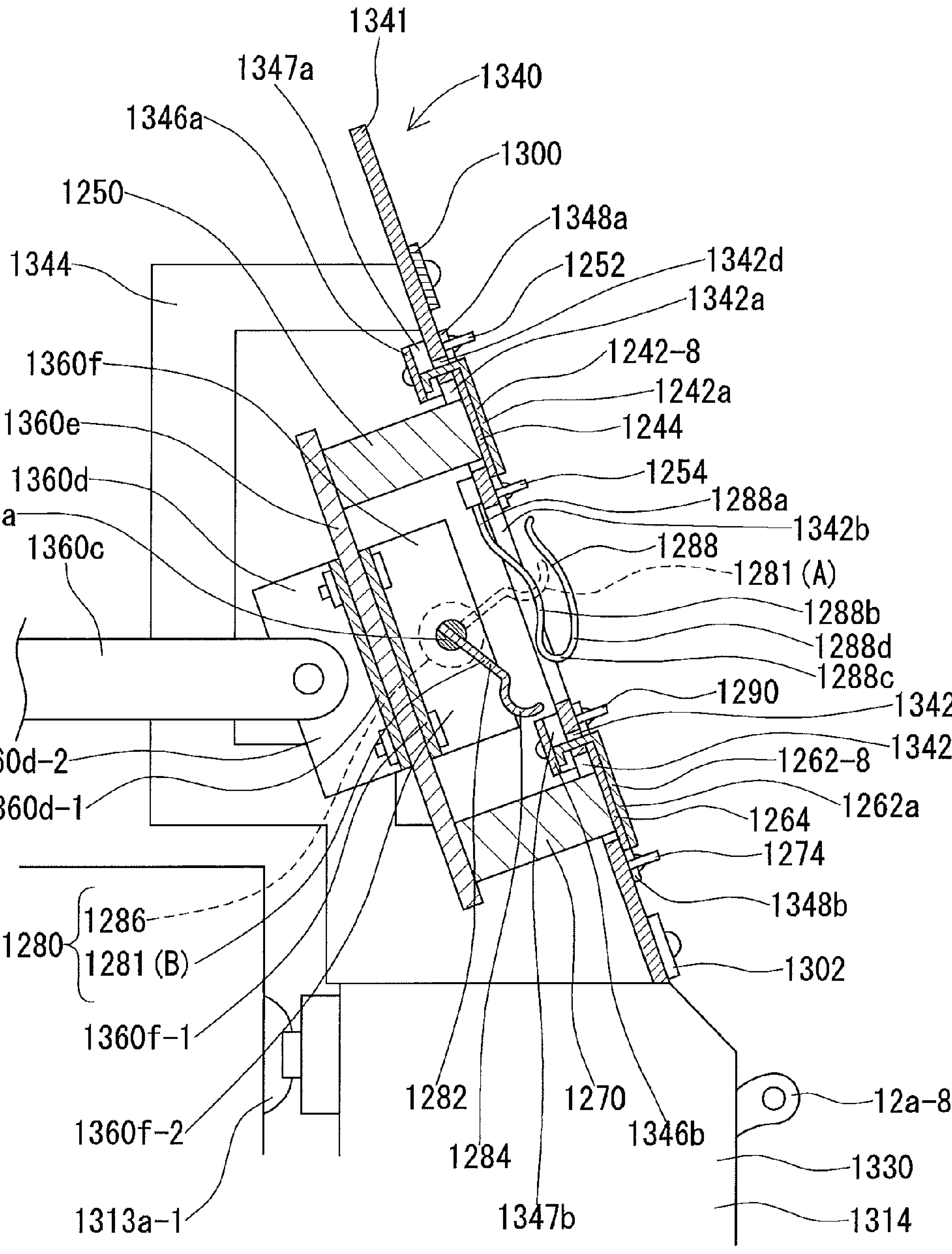

1341
1347a
1340
1346a
1300
1250
1348a
1344
1252
1342d
1342a
1242-8
1360f
1242a
1360e
1244
1254
1360d
1288a
1286a
1342b
1360c
1288
1281 (A)
1288b
1288d
1288c
1290
1342e
1342c
1360d-2
1262-8
1360d-1
1262a
1264
1274
1348b
1286
1280
1281 (B)
1302
1360f-1
1282
1270
12a-8
1360f-2
1284
1346b
1330
1313a-1
1347b
1314

FIG. 35

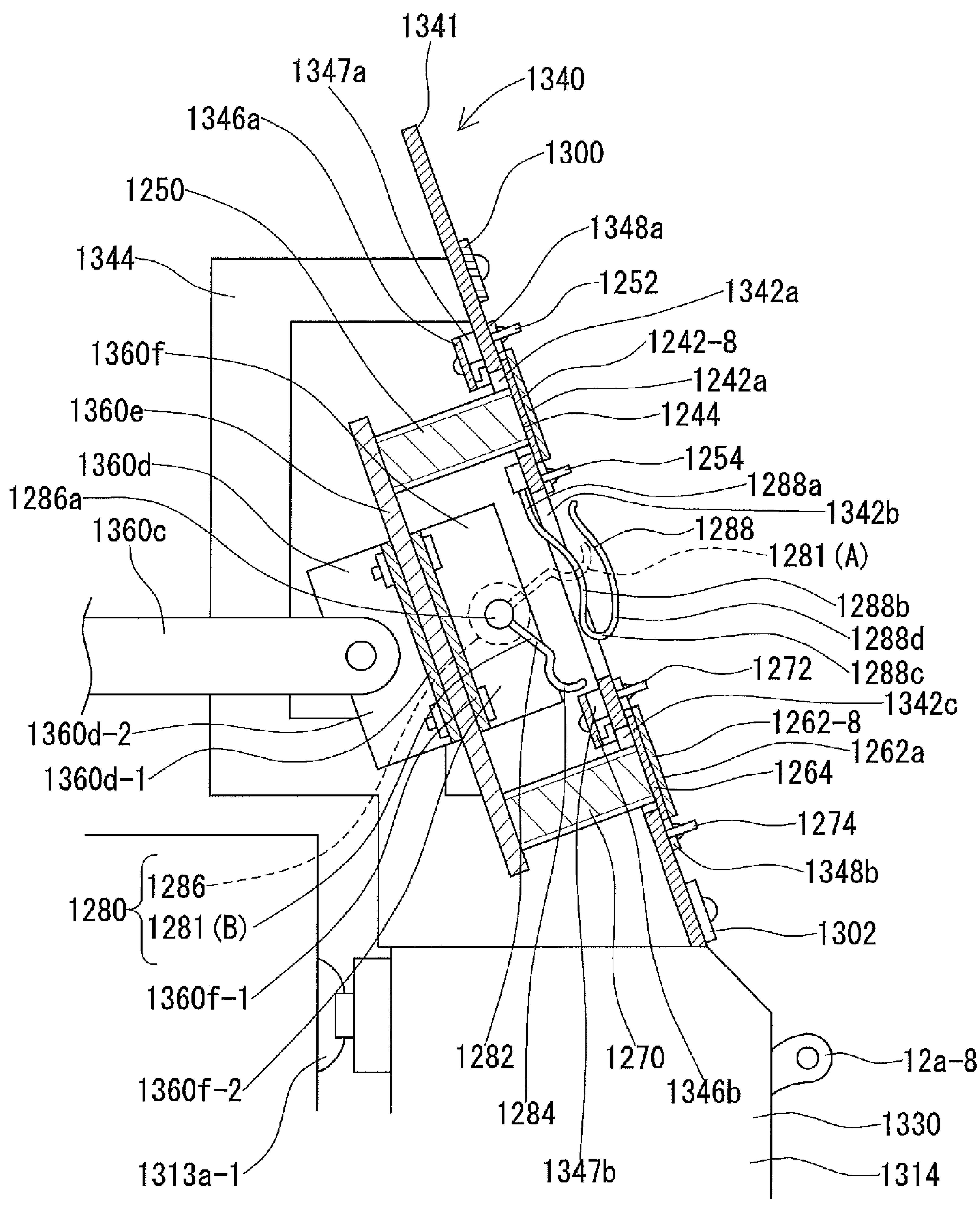

1341
1347a
1340
1346a
1300
1250
1348a
1344
1252
1342a
1242-8
1360f
1242a
1360e
1244
1254
1360d
1288a
1286a
1342b
1360c
1288
1281 (A)
1288b
1288d
1288c
1272
1342c
1360d-2
1262-8
1262a
1360d-1
1264
1274
1348b
1286
1280
1281 (B)
1302
1360f-1
1282
1270
12a-8
1360f-2
1284
1346b
1330
1313a-1
1347b
1314

FIG. 36

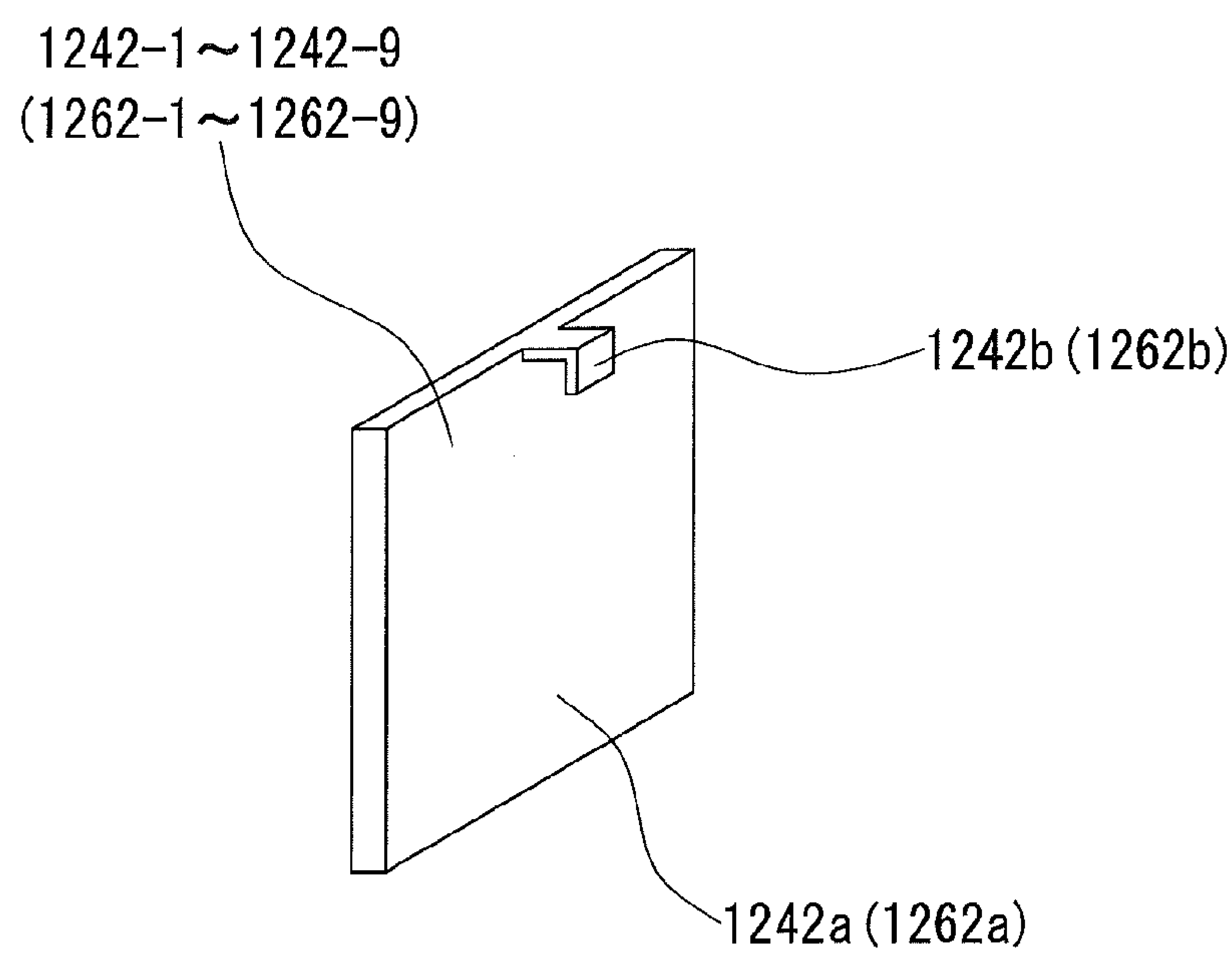


FIG. 37

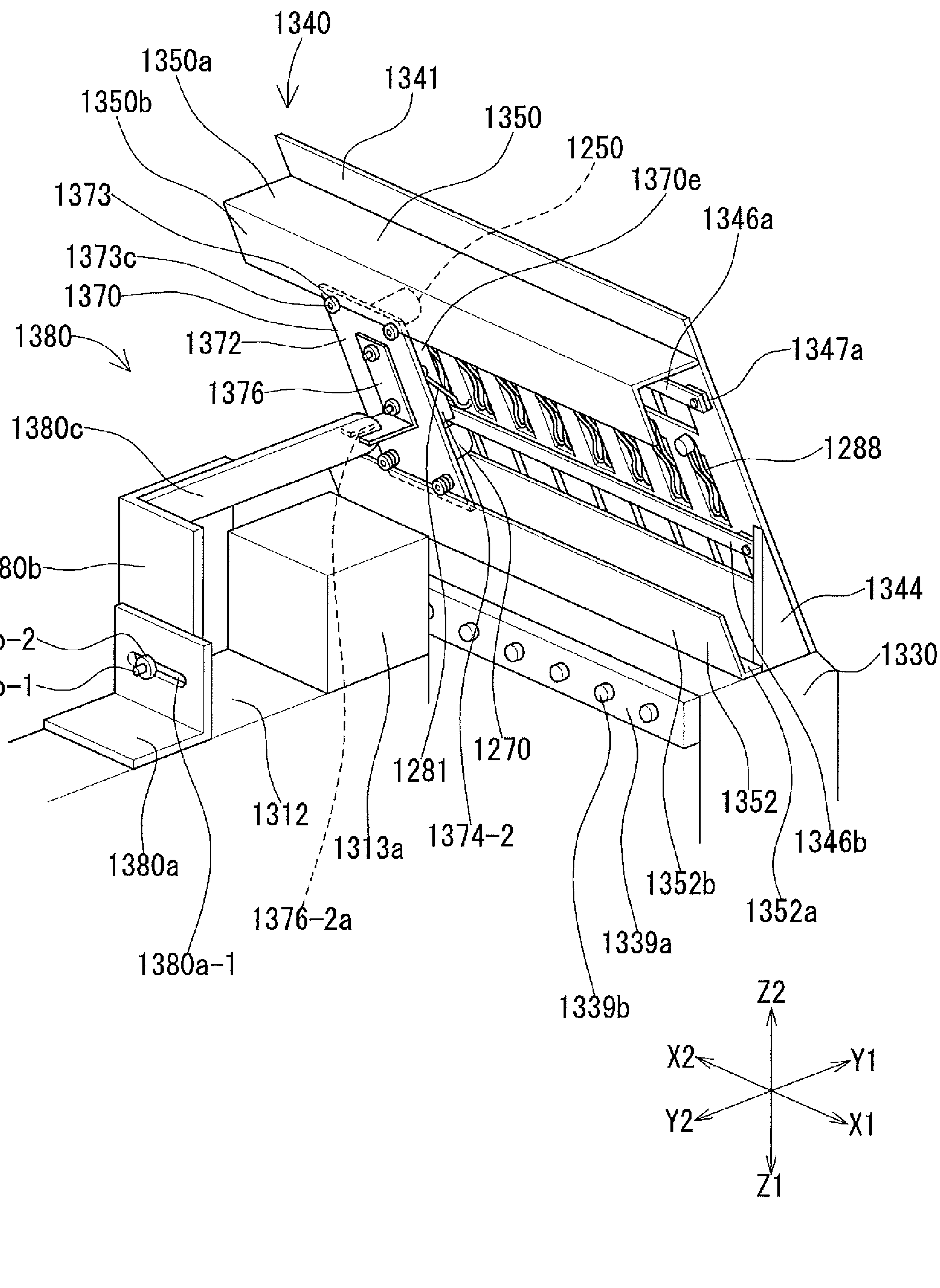

1340
1350a
1341
1350b
1350
1250
1370e
1373
1346a
1373c
1370
1380
1372
1347a
1376
1380c
1288
1380b
1344
1380b-2
1330
1380b-1
1281
1270
1352
1312
1313a
1374-2
1346b
1380a
1352b
1376-2a
1352a
1339a
1380a-1
1339b
Z2
X2
Y1
Y2
X1
Z1

FIG. 38

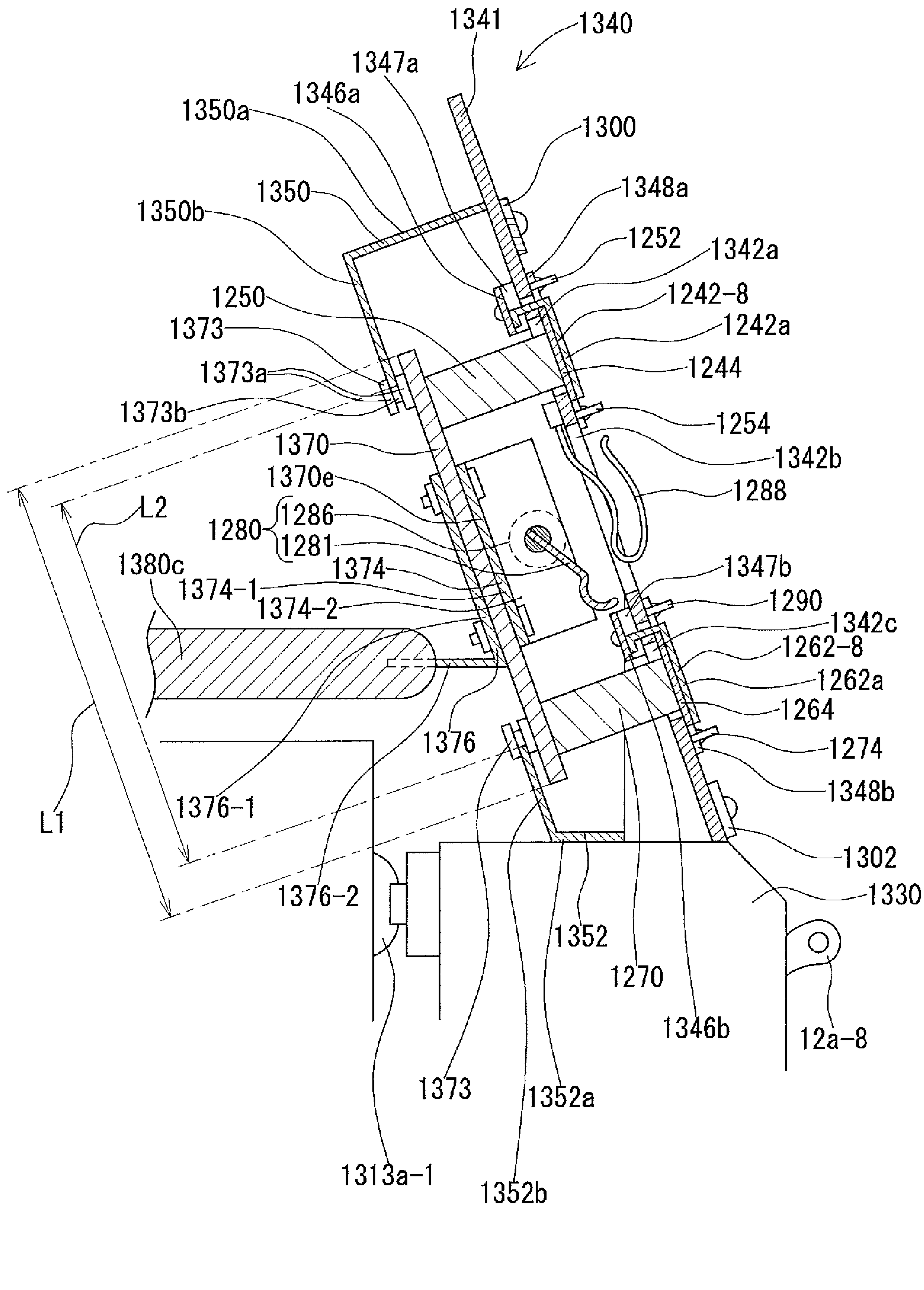

1341
1340
1347a
1346a
1350a
1300
1350
1348a
1350b
1252
1342a
1242-8
1250
1242a
1373
1244
1373a
1373b
1254
1370
1342b
1370e
1288
1280
1286
1281
L2
1380c
1374
1347b
1374-1
1290
1374-2
1342c
1262-8
1262a
1264
1376
1274
1348b
L1
1376-1
1302
1376-2
1330
1352
1270
1346b
12a-8
1373
1352a
1313a-1
1352b

FIG. 39

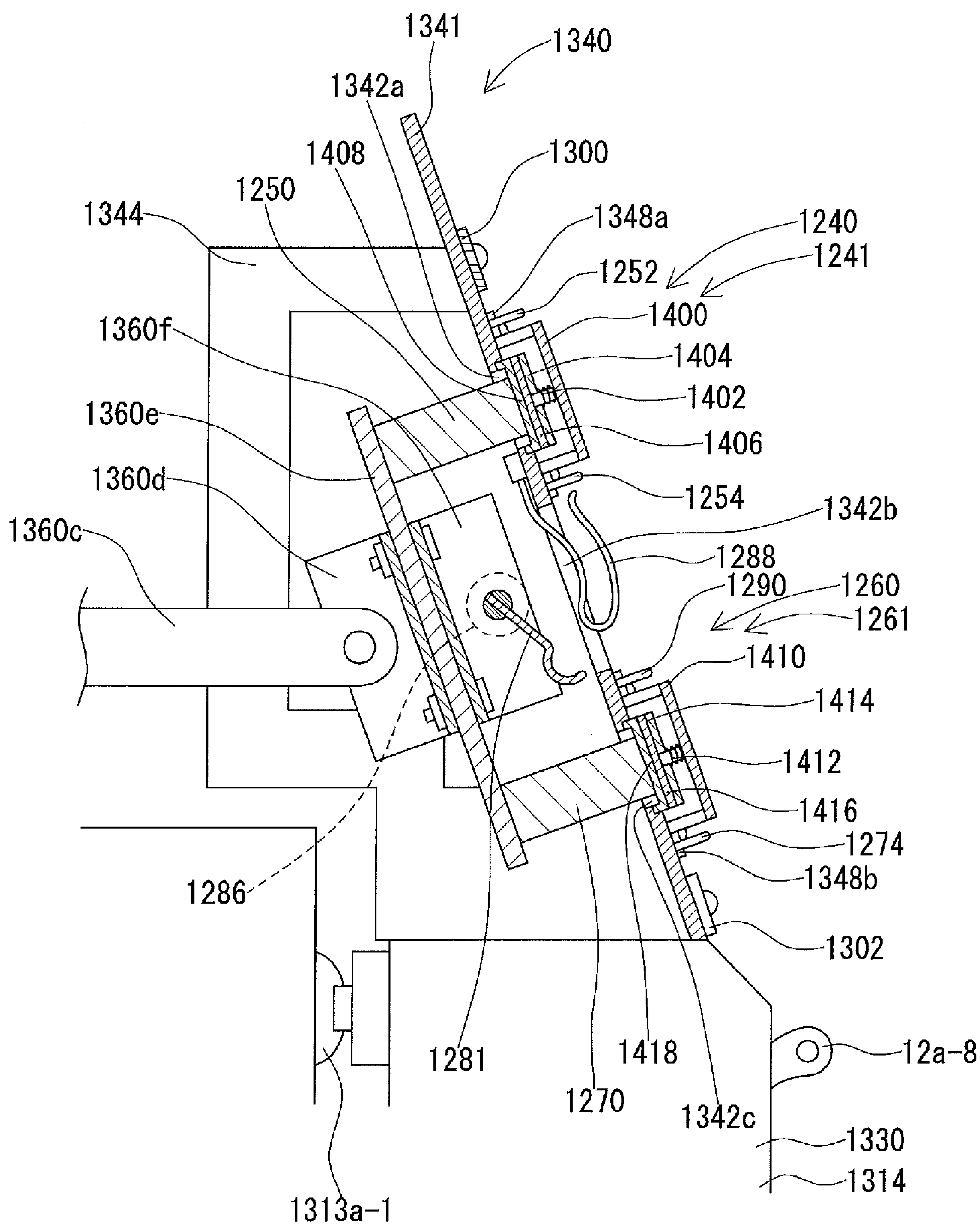

1341
1340
1342a
1300
1408
1250
1344
1348a
1240
1252
1241
1400
1360f
1404
1402
1360e
1406
1360d
1254
1342b
1360c
1288
1290
1260
1261
1410
1414
1412
1416
1274
1348b
1286
1302
1281
1418
12a-8
1270
1342c
1330
1314
1313a-1

FIG. 40

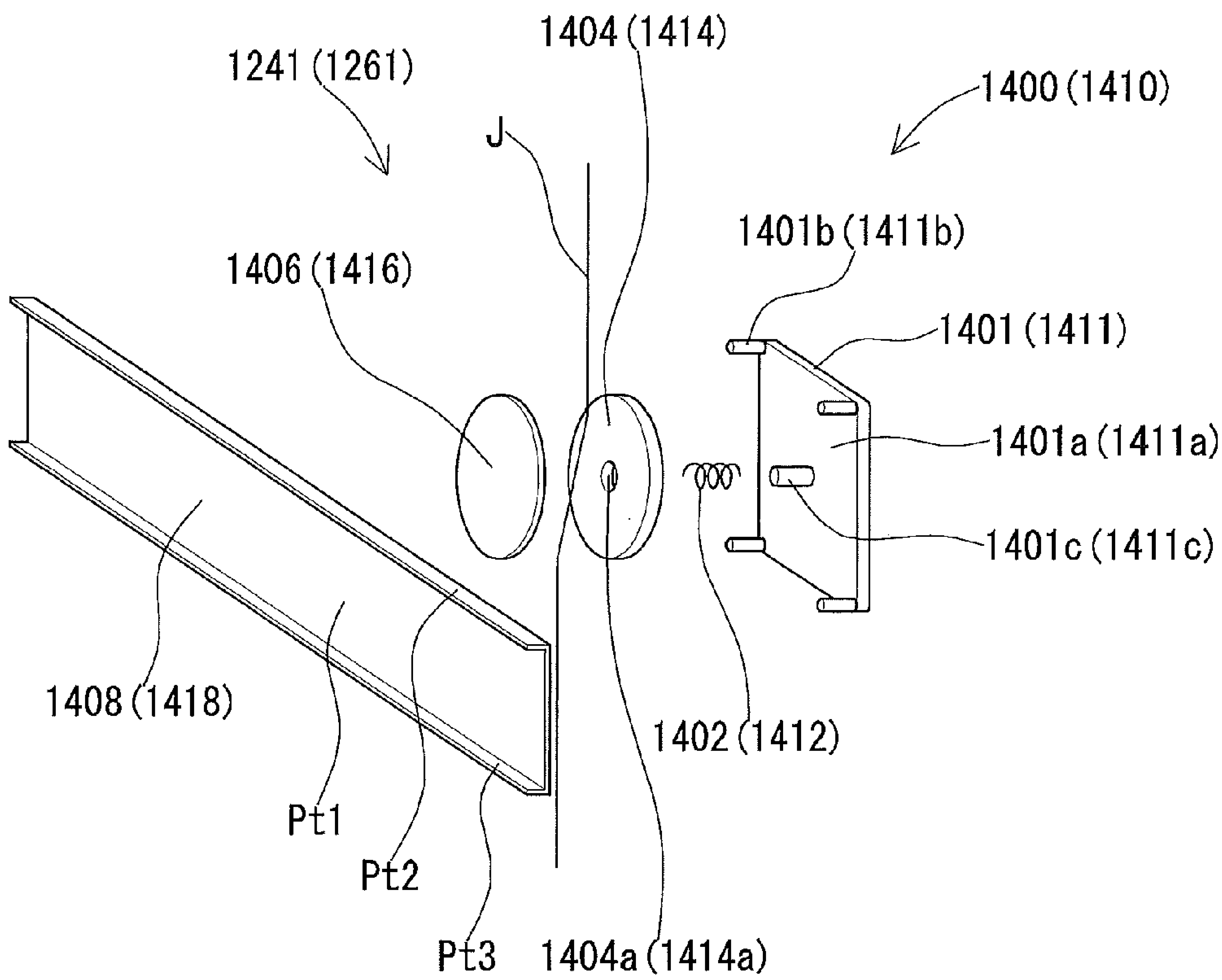

1404 (1414)
1241 (1261)
1400 (1410)
J
1401b (1411b)
1406 (1416)
1401 (1411)
1401a (1411a)
1401c (1411c)
1408 (1418)
1402 (1412)
Pt1
Pt2
Pt3
1404a (1414a)

FIG. 41

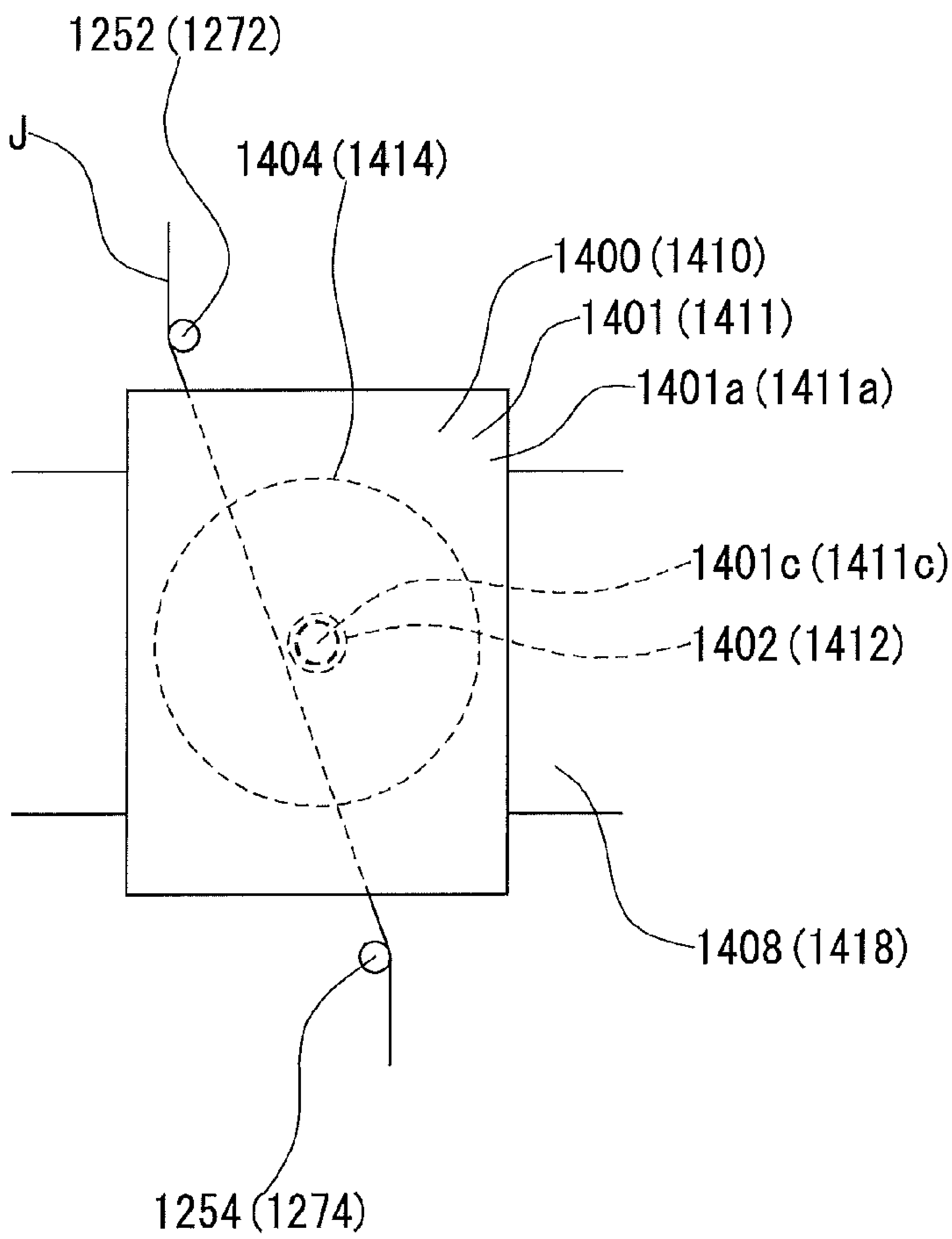

1252 (1272)
J
1404 (1414)
1400 (1410)
1401 (1411)
1401a (1411a)
1401c (1411c)
1402 (1412)
1408 (1418)
1254 (1274)

FIG. 42

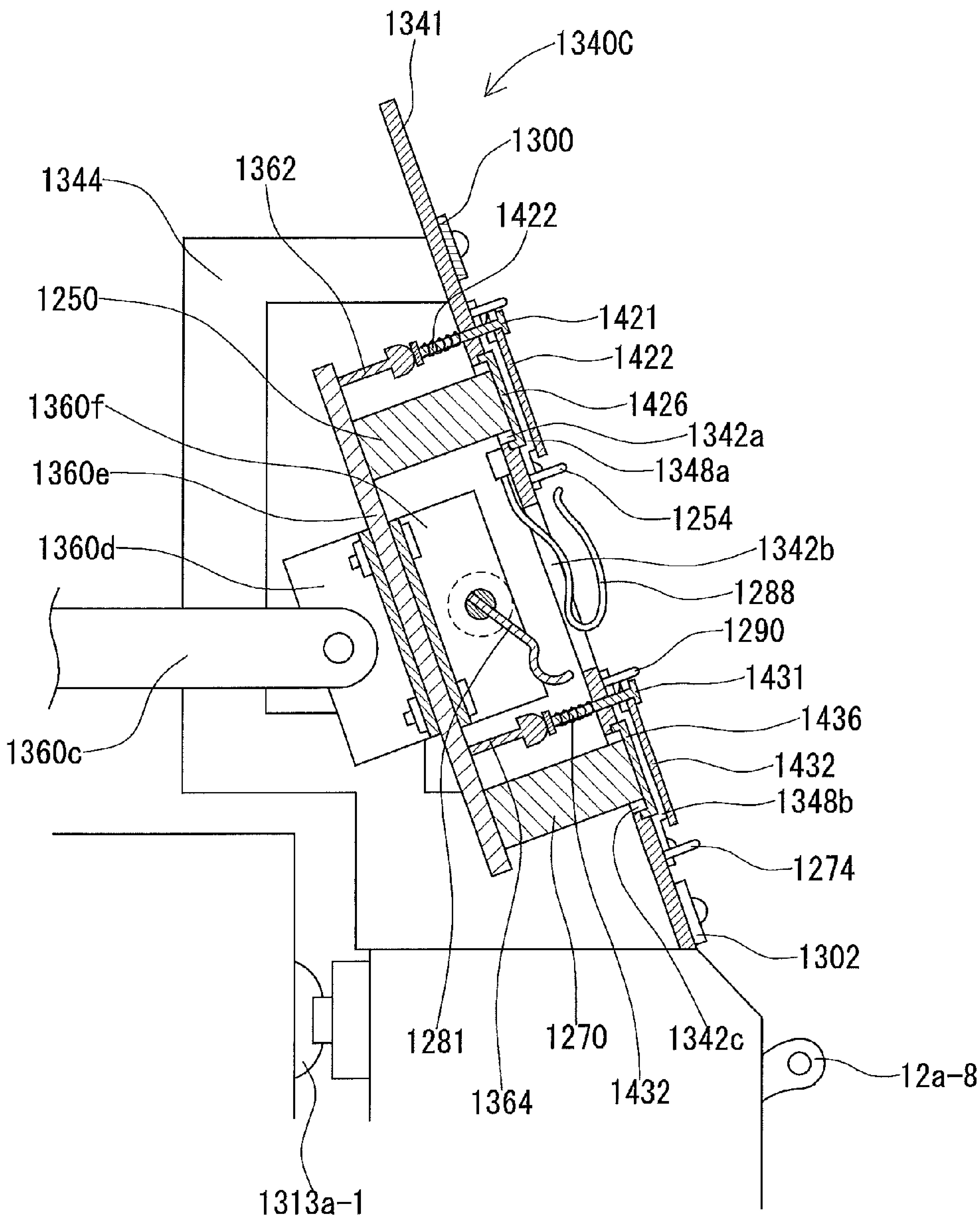
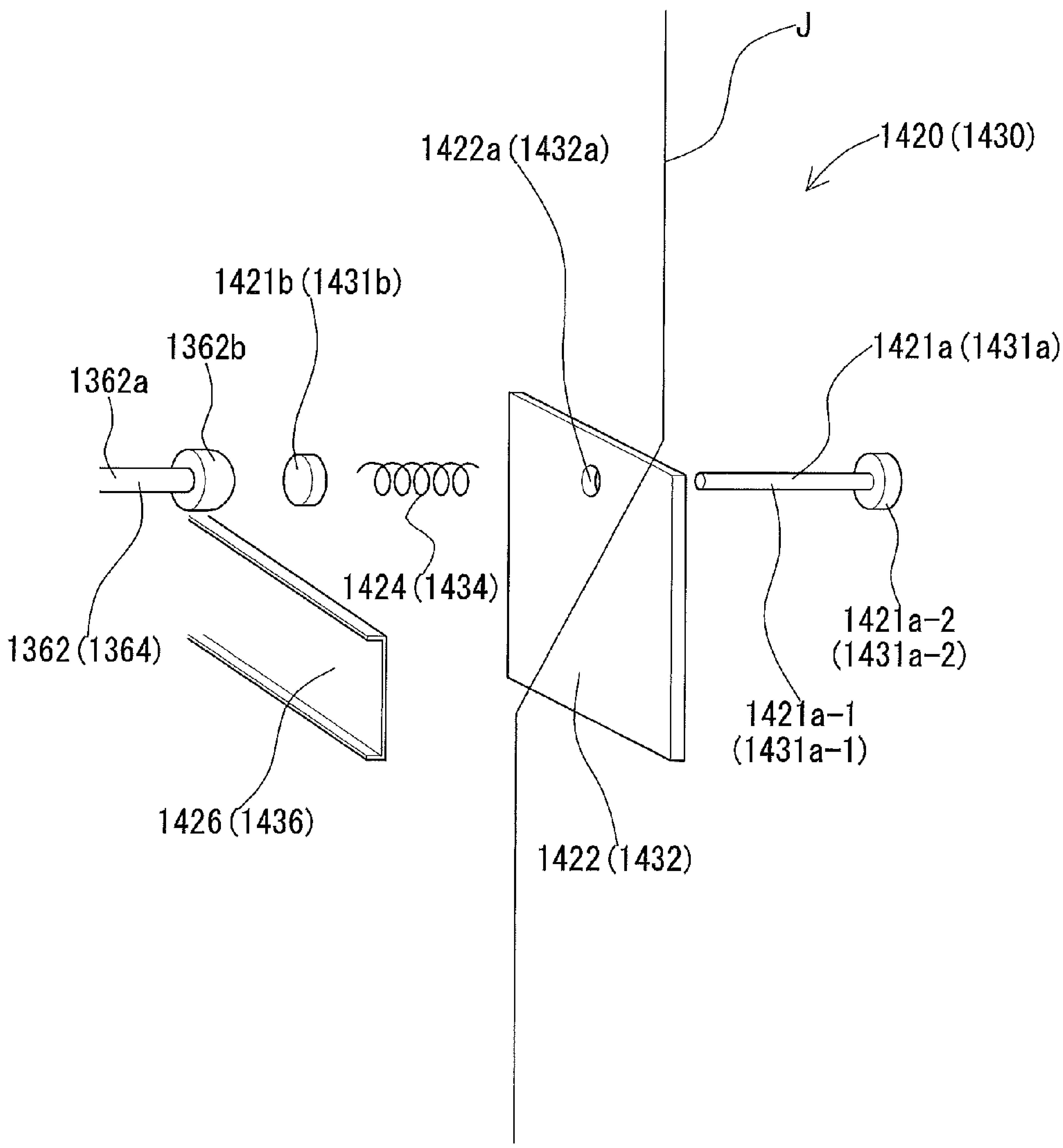

1341
1340C
1300
1344
1362
1422
1250
1421
1422
1426
1360f
1342a
1348a
1360e
1254
1342b
1360d
1288
1290
1431
1436
1360c
1432
1348b
1274
1302
1281
1270
1342c
1364
1432
12a-8
1313a-1

FIG. 43



J
1420 (1430)
1422a (1432a)
1421b (1431b)
1362b
1362a
1421a (1431a)
1424 (1434)
1362 (1364)
1421a-2
(1431a-2)
1421a-1
(1431a-1)
1426 (1436)
1422 (1432)

FIG. 44

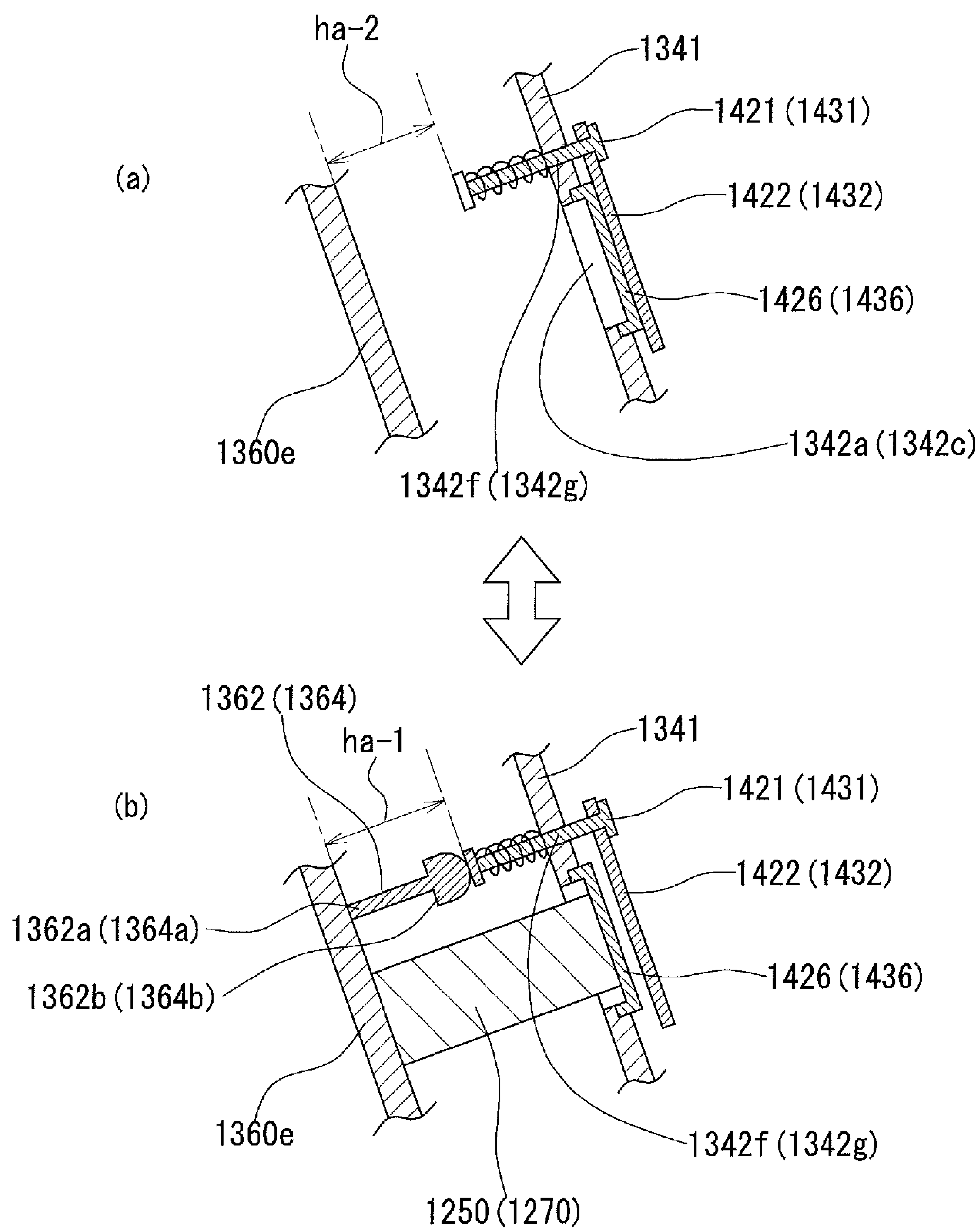

ha-2
1341
1421 (1431)
(a)
1422 (1432)
1426 (1436)
1360e
1342a (1342c)
1342f (1342g)
1362 (1364)
ha-1
1341
1421 (1431)
(b)
1422 (1432)
1362a (1364a)
1426 (1436)
1362b (1364b)
1360e
1342f (1342g)
1250 (1270)

FIG. 45

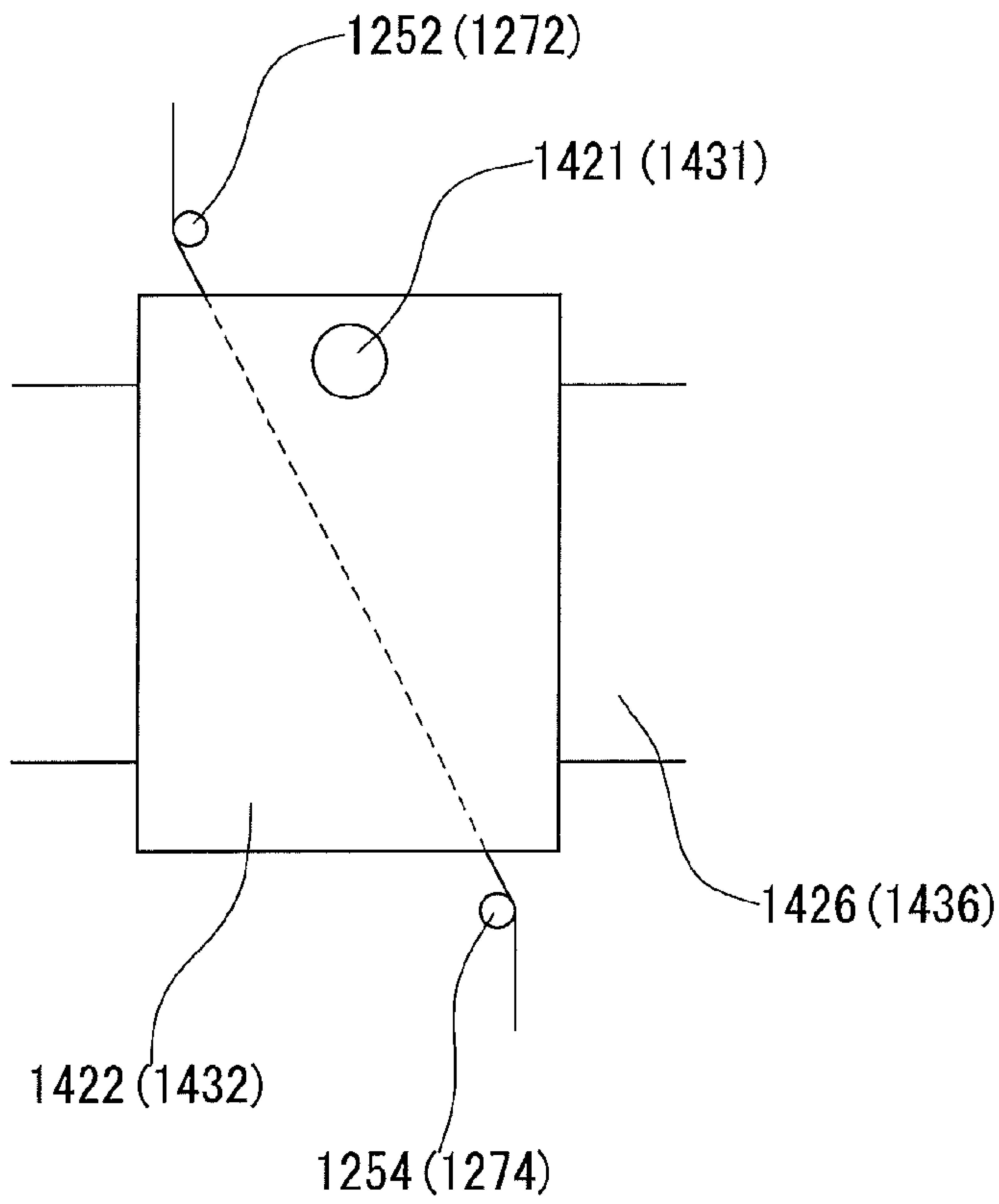


FIG. 46

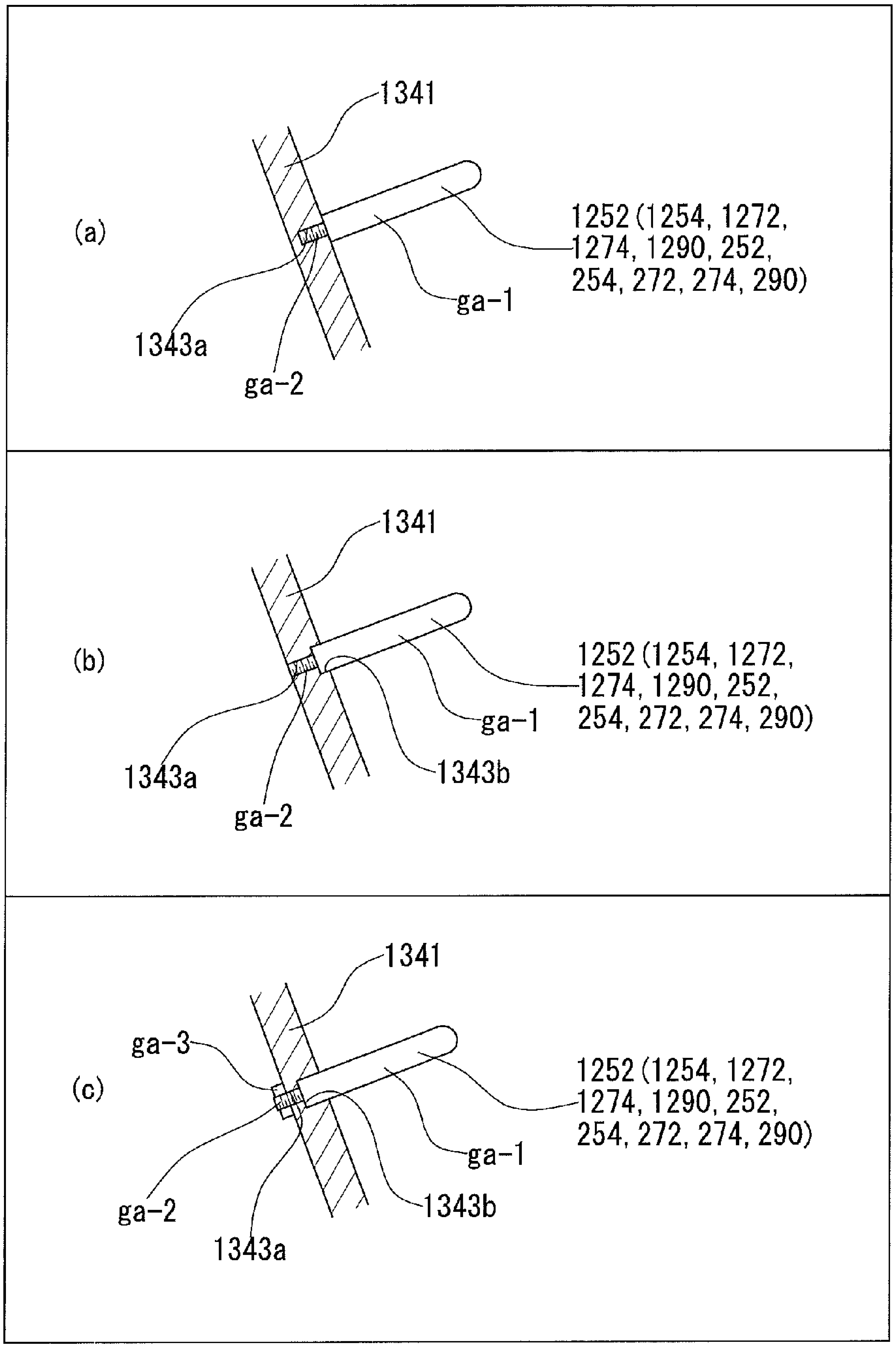

(a)
1341
1252 (1254, 1272, 1274, 1290, 252, 254, 272, 274, 290)
ga-1
1343a
ga-2
(b)
1341
1252 (1254, 1272, 1274, 1290, 252, 254, 272, 274, 290)
ga-1
1343a
1343b
ga-2
(c)
1341
ga-3
1252 (1254, 1272, 1274, 1290, 252, 254, 272, 274, 290)
ga-1
ga-2
1343b
1343a

FIG. 47

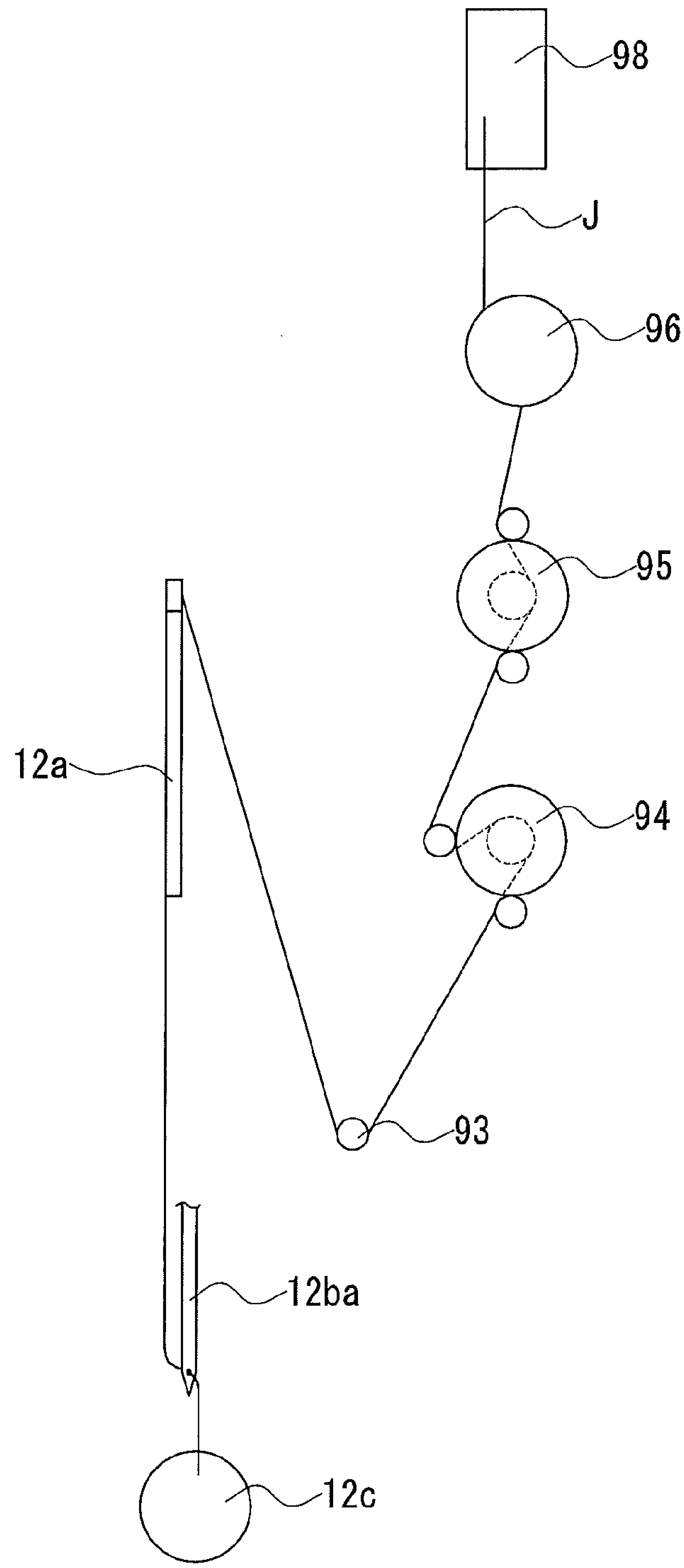
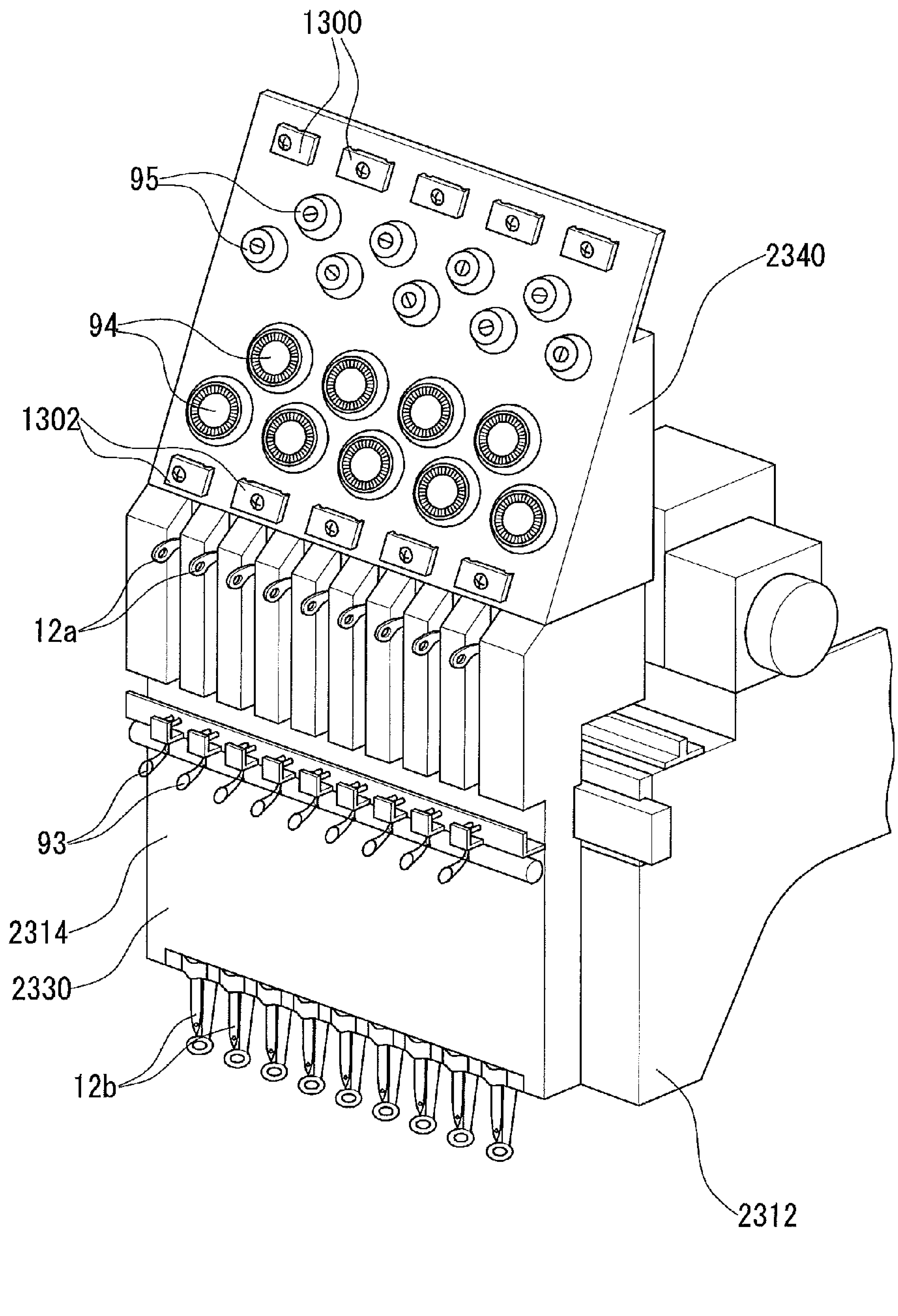


FIG. 48



SEWING MACHINE

TECHNICAL FIELD

The present invention relates to a sewing machine (particularly to an embroidery sewing machine) and, particularly, to control of needle thread tension in a sewing machine.

BACKGROUND ART

As shown in FIG. **47**, in a related-art sewing machine, a needle thread J runs out of a thread roll **98** wound around a needle thread bobbin and reaches a thread take-up lever **12***a* via a pretension component **96**, a tension disc **95**, a rotary tension component **94**, and a tension spring (generally called a "high tension spring") **93** and subsequently a sewing needle **12***ba*.

The related-art sewing machine is also configured as shown in FIG. **48**. A needle bar case **2314** that slides in a horizontal direction with respect to an arm **2312** has a needle bar case main body **2330** equipped with the thread take-up levers **12***a*, needle bars **12***b*, the tension springs **93**, and others; and a needle thread adjustment member mounting section **2340** fixedly put on an upper surface of the needle bar case main body **2330**. The needle thread adjustment member mounting section **2340** is equipped with the tension discs **95** and the rotary tension components **94** for adjusting tension of respective needle threads. Needle thread guides **1300** are placed above the respective tension discs **95**, and needle thread guides **1302** are placed beneath the respective rotary tension components **94**.

The related-art sewing machine is also equipped with a machine sewing thread feeding device described in connection with Patent Document 1. In relation to the machine sewing thread feeding device described in connection with Patent Document 1, the thread feeding device has a needle thread downstream gripper, an upper looper thread downstream gripper, and a lower looper thread downstream gripper. The needle thread downstream gripper grips a needle thread guided from a needle thread upstream gripper; the upper looper thread downstream gripper grips an upper looper thread guided from an upper looper thread upstream gripper; and the lower looper thread downstream gripper grips a lower looper thread guided from a lower looper thread upstream gripper. At the time of formation of a stitch, the needle thread downstream gripper is opened, whereupon the needle thread is drawn from the needle thread downstream gripper by a stitch forming device. During cloth feeding, the needle thread downstream gripper is closed. Similarly, at the time of formation of a stitch, the upper looper thread downstream gripper is opened, whereupon an upper looper thread is drawn from the upper looper thread downstream gripper by the stitch forming device. During cloth feeding, the upper looper thread downstream gripper is likewise closed. Moreover, at the time of formation of a stitch, the lower looper thread downstream gripper is also opened, whereupon a lower looper thread is drawn from the lower looper thread downstream gripper by the stitch forming device. During cloth feeding, the lower looper thread downstream gripper is closed. During feeding of a cloth, the upstream grippers are opened, and the downstream grippers are closed. A draw-in member moves while drawing a thread, thereby piling up the thread. On the contrary, during formation of a stitch, the upstream grippers are closed, and the downstream grippers are opened, the draw-in member moves to a position where the member does not draw the thread, and the thread is released.

The present applicants also filed the embroidery sewing machine described in connection with Patent Document 2.

RELATED ART DOCUMENT

Patent Document

Patent Document 1: Unexamined Japanese Patent Application Laid-Open No. 9-19583

Patent Document 2: Unexamined Japanese Patent Application Laid-Open No. 2010-178785

DISCLOSURE OF THE INVENTION

Problem that the Invention is to Solve

However, in the related-art configuration shown in FIG. **47**, the needle thread J constantly undergoes frictional resistance developed in the tension disc **95** and frictional resistance developed in the rotary tension component **94**. Since the frictional resistance is unstable (variable) as a resistance value, difficulty is encountered in controlling tension on the needle thread for each stitch. Moreover, when one head has a plurality of needle bars or when the sewing machine is a multi-head embroidery sewing machine, it is difficult to impart a same resistance value to a needle thread on a tension disc and a needle thread on a rotary tension component for each needle thread of one head. For these reasons, making tension exerted on respective needle threads uniform is difficult.

In the configuration shown in FIG. **47**, the needle thread J is drawn from the thread roll **98** when the thread take-up lever **12***a* is pulled up. On this occasion, the needle thread J undergoes the frictional resistance developed in the tension disc **95** and the frictional resistance developed in the rotary tension component **94**. Further, since the frictional resistance is unstable, the needle thread J cannot be smoothly drawn from the thread roll **98**. Further, since the needle thread J is drawn when the take-up lever **12***a* has been pulled up, the needle thread J is drawn in a short period of time. The frictional resistance developed in the tension disc **95** and the frictional resistance developed in the rotary tension component **94** are exerted on the needle thread J; hence, the needle thread J may be cut by friction.

When the needle thread J has broken, the configuration shown in FIG. **47** can detect a threadbreak by means of non-rotation of the rotary tension component **94**. However, slippage occurs between the rotary tension component **94** and the needle thread J. Therefore, there may be a case where the rotary tension component **94** will not rotate even when there is not occurrence of a thread break. For these reasons, the break of a needle thread cannot be accurately detected.

Moreover, in the machine sewing thread feeding device described in connection with Patent Document 1, only the draw-in membermoves, at the time of formation of a stitch, to the position where the thread is not drawn in. Accordingly, thread tension cannot be controlled. In an ordinary sewing machine, a period during which the thread take-up levers move upwards corresponds not to a period of formation of stitches but to a cloth feeding period. In the thread feeding device described in connection with Patent Document 1, since the downstream grippers are closed in the period during which the thread take-up levers ascend, controlling thread tension is originally impossible. In the thread feeding device described in connection with Patent Document 1, the draw-in member draws a given quantity of thread, and therefore an excess or deficiency may occur in the quantity of accumulated threads during cloth feeding operation depending on the quantity of thread consumed by each of stitches.

Accordingly, the problems that the present invention is to solve are to provide a needle thread tension controller that can control a magnitude of tension on a needle thread; in particular, tension on a needle thread for each stitch, make tension on the respective needle threads equal in the case of a multi-needle head or a multi-head embroidery sewing machine, and smoothly draw needle threads at the time of pulling of needle threads; that has a small possibility of breaking threads and that is easy to detect a thread break accurately when the thread break has occurred; and that does not cause any excess or deficiency of the quantity of accumulated thread, which would otherwise be caused by drawing a needle thread.

Means for Solving the Problem

The present invention has been conceived to solve the problem. In a first configuration, the present invention provides a sewing machine comprising: a thread take-up lever (**12***a*, **12***a*-**1** to **12***a*-**9**) formed in a swayable manner; a needle thread control section (**30**, **230**) that is disposed at an upstream position on a needle thread path of the thread take-up lever and that includes an upstream grip section (**40**, **240**, **1240**) which includes an upstream grip section main body (**41**, **241**, **1241**) for pinching to thereby grip a needle thread and an upstream actuation section (**50**, **250**) for switching, with respect to the upstream grip section main body, between a closed state in which the needle thread is gripped and an open state in which a needle thread is released from a gripped state, a downstream grip section (**60**, **260**, **1260**) which is disposed at a downstream position on a needle thread path of the upstream grip section and which includes a downstream grip section main body (**61**, **261**, **1261**) for pinching to thereby grip a needle thread and a downstream actuation section (**70**, **270**) for switching, with respect to the downstream grip section main body, between a closed state in which the needle thread is gripped with respect to the downstream grip section main body and an open state in which the needle thread is released from a gripped state, and a turning section (**80**, **280**, **1280**) which turns the needle thread existing between the upstream grip section main body and the downstream grip section main body (or a position on the needle thread existing between the upstream grip section main body and the downstream grip section main body) and which has an turning arm (**81**, **281**, **1281**) contacting the needle thread (or "contacting the needle thread when turning the needle thread") and a needle thread motor (**86**, **286**, **1286**) for turning the turning arm; and a control section (**90**), in a control zone for each stitch, that—in a torque control zone including at least a portion of a zone from a bottom dead point to a top dead point of the thread take-up lever during which the thread take-up lever draws the needle thread with respect to processed fabric to be sewn with the needle thread—controls the needle thread motor in accordance with a torque value in such a way that tension is imparted to the needle thread against a direction in which the thread take-up lever draws the needle thread while the upstream grip section main body is closed and while the downstream grip section main body is opened, thereby imparting rotating force to the turning arm and that—in a position control zone which is at least a portion of a zone other than the torque control zone achieved while the upstream grip section main body is opened and while the downstream grip section main body is closed—controls the needle thread motor in accordance with angle position data pertaining to the needle thread motor in such a way that an angle of the needle thread motor returns to an initial angle position of the needle thread motor which is a rotational position of the needle thread motor, thereby imparting rotating force to the turning arm to thus draw the needle thread from an upstream position.

In the sewing machine having the first configuration, a needle thread is subjected to torque control in the torque control zone. Therefore, the magnitude of tension on the needle thread can be controlled. A torque value is set for each stitch, whereby torque control can be performed for each stitch. Tension on the needle thread can be controlled for each stitch, so that seam hardness can be controlled for each stitch.

Even in the case of a multi-needle head or when a stitch is formed from different needle threads, tension on the needle thread can be equally controlled by means of making torque values equal. Further, even in the case of a multi-head embroidery sewing machine, torque values employed in the torque control zone are made common to the heads, whereby tension on the needle threads exerted by the respective heads can be made equal.

Further, the needle thread control section is provided in place of the tension disc and the rotary tension component in the related-art sewing machine. As a result, in the position control zone where the needle thread is drawn, the upstream grip section main body becomes open. Frictional resistance attributable to the tension disc and the rotary tension component does not exist in an upstream position with respect to the turning arm of the turning section. Further, since the downstream grip section main body becomes closed, movements of the thread take-up lever will not pose any problem at the time of drawing of the needle thread. Consequently, the needle thread can be smoothly drawn from the thread roll, so that the risk of occurrence of a thread break can be made small.

If a break has occurred in the needle thread, the turning arm will not be pulled, in the torque control zone, in a direction opposite to the direction in which the rotating force of the needle thread motor is imparted when the thread take-up lever moves to its top dead center. Hence, occurrence of a thread break can be detected by detecting that the turning arm does not turn in a direction opposite to the direction in which the rotating force of the needle thread motor is imparted. Further, when there are not any thread breaks, the turning arm turns, in the torque control zone, in the direction opposite to the direction in which the needle thread motor imparts rotating force. Hence, occurrence of a thread break can be detected accurately.

In the position control zone, rotating force is imparted to the turning arm in accordance with angle position data pertaining to the needle thread motor such that the angle of the needle thread motor returns to the initial angle position of the needle thread motor that is a rotational position of the needle thread motor. The needle thread can therefore be drawn by an amount corresponding to a quantity of thread consumed as a result of pulling of the turning arm in the direction opposite to the direction in which the rotating force of the needle thread motor is imparted, so that an excess or deficiency of the quantity of accumulated thread, which would otherwise be caused by drawing a needle thread, will not occur.

In the first configuration, the thread take-up lever can also be taken as a "thread take-up lever (**12***a*, **12***a*-**1** to **12***a*-**9**) into which a needle thread (a needle thread to be inserted into a sewing needle) is inserted and that sways around the rotating center."

In a second configuration based on the first configuration, the sewing machine further comprises: an arm (**312**, **1312**) making up an enclosure of the sewing machine; a needle bar case (**314**, **1314**) that is provided so as to be slidable in a horizontal direction with respect to the arm and that includes first opening sections (**316***b*, **1342***b*) made at positions between the upstream grip section main body and the downstream grip section main body in a vertical direction such that a leading end of the turning arm of the turning section can be exposed to the front side (or the "front side may also be opposite to the arm side"), a second opening section (**316***a*, **1342***a*) which is provided above the first opening section and onto which the upstream magnet section fronts, and a third opening section (**316***c*, **1342***c*) that is placed below the first opening sections and on which a downstream magnet section fronts; a plurality of needle bars (**12***b*-**1** to **12***b*-**9**) provided in a needle bar case; and needle thread supporting members (**288**, **1288**) that each is provided in the needle bar case and that each supports the needle thread in the horizontal direction at the position of each of the first opening sections (or the needle thread supporting members can also be embodied as a "needle thread supporting members that each is provided in the needle bar case and horizontally support the needle thread with respect to the front side of each of the first opening sections"), wherein the thread take-up lever is placed while being exposed from a position in the needle bar case below the downstream grip section to a front; the turning arm is turned while remaining in contact with the needle thread supported by the needle thread supporting member, thereby turning the needle thread; the upstream grip section main body is placed on a front side of the needle bar case and, has plurality of upstream first plate-like sections (**242-1** to **242-6**, **1242***a*, **1404**, **1422**) which is formed into a shape of a plate from a magnetic substance; that is, a material attracted by the magnet and which is provided in the needle bar case and an upstream second plate-like section (**244**, **1244**, **1408**, **1426**) which is provided at back side of the upstream first plate-like sections and on a front side of the second opening section and which is formed into a shape of a plate from a non-magnetic substance unattracted by the magnet; the upstream actuation section is a magnet section serving as the upstream magnet section and secured to the arm-side secured in the direction of the arm) at a back side of the upstream second plate-like section and switches between a closed state in which the upstream first plate-like section is attracted by magnetic force, to thus pinch and grip the needle thread between the upstream first plate-like section and the upstream second plate-like section and an open state in which attraction caused by the magnetic force is released to thereby release the needle thread from the gripped state; the downstream grip section main body is placed on a front side of the needle bar case and below the upstream grip section main body and has a plurality of downstream first plate-like sections (**262-1** to **262-6**, **1262***a*, **1414**, and **1432**) which are formed from a magnetic substance which is attracted by a magnet into a shape of a plate and which are provided in the needle bar case and a downstream second plate-like section (**264**, **1264**, **1418**, **1436**) which is provided at back side of the downstream first plate-like sections and on a front side of the second opening section and which is formed into a shape of a plate from a non-magnetic substance unattracted by the magnet; and the downstream actuation section is a magnet section serving as the downstream magnet section and secured to the arm-side at a back side of the downstream second plate-like section and switches between a closed state in which the downstream first plate-like section is attracted by magnetic force, to thus pinch and grip the needle thread between the downstream first plate-like section and the downstream second plate-like section and an open state in which the needle thread is released from the gripped state by means of canceling attraction caused by the magnetic force.

When the structure including the upstream grip section, the downstream grip section, and the turning section is applied to a multi-needle head, the sewing machine can be configured by providing only one each of the upstream magnet section of the upstream grip section, the downstream magnet section of the downstream grip section, and the turning section. Accordingly, the sewing machine can be provided with an efficient structure while its manufacturing cost is curtailed.

In the second configuration, the configuration of the needle bar case can also be embodied as a "needle bar case (**314**, **1314**) provided so as to be slidable with respect to the arm. In the needle bar case, a first opening section (**316***b*, **1342***b*) is provided between the upstream grip section main body and the downstream grip section main body in the vertical direction on the front side that is opposite to the arm side, in such a way that the leading end of the turning arms of the turning section can be exposed from the interior of the needle bar case. A second opening section (**316***a*, **1342***a*) on that the upstream magnet section fronts is provided at a position above the first opening section. A third opening section (**316***c*, **1342***c*) on that the downstream magnet section fronts is provided at a position below the first opening section."

In a third configuration based on the first or second configuration, the control section performs control operation in accordance with torque data whose torque value is specified for each stitch in the torque control zone and detects, at a starting point of the position control zone, a current angle position of the needle thread motor in the position control zone, generates angle correspondence data which specify an angle of the needle thread motor from the current angle position to an initial angle position of the needle thread motor for each angle of a main spindle motor representing a rotational position of the main spindle motor which rotates a main spindle for transmitting power to the thread take-up lever, and controls a position of the needle thread motor to its angle of the needle thread motor corresponding to the angle of the main spindle motor as the angle of the main spindle motor changes as a result of rotation of the main spindle motor.

Since a torque value is specified for each stitch by means of the torque data, tension on the needle thread can be controlled on a per-stitch basis during torque control. During position control, angle correspondence data are prepared. Hence, angle position control of the needle thread motor can be performed in accordance with the angle correspondence data.

The following configuration can also be adopted. Specifically, there is provided a sewing machine comprising:

a thread take-up lever (**12***a*, **12***a*-**1** to **12***a*-**6**) that enables insertion of a needle thread to be inserted into a sewing needle and that sways around a rotating center;

a main spindle (**22**) that is rotated by a main spindle motor (**20**) and that transmits power to the thread take-up lever;

a needle thread control section (**30**, **230**) that is provided at an upstream position along the needle tread and that includes

an upstream grip section (**40**, **240**) having an upstream grip section main body (**41**, **241**) that pinches to thereby grip the needle thread and an upstream actuation section (**50**, **250**) that switches, with respect to the upstream grip section main body, between a closed state in which the needle thread is gripped and an open state in which a needle thread is released from a gripped state,

a downstream grip section (**60**, **260**) which is disposed at a downstream position on a needle thread path of the upstream grip section and which has a downstream grip section main body (**61**, **261**) for pinching to thereby grip the needle thread and a downstream actuation section (**70**, **270**) for switching, with respect to the downstream grip section main body, between a closed state in which the needle thread is gripped and an open state in which the needle thread is released from a gripped state, and

a turning section (**80**, **280**) which turns a position on the needle thread located between the upstream grip section main body and the downstream grip section main body and which includes a turning arm (**81**, **281**) remaining in contact with the needle thread and a needle thread motor (**86**, **286**) for turning the turning arm; and

a control section (**90**) that—in a torque control zone of control zone for each stitch including at least a portion of a zone from a bottom dead point to a top dead point of the thread take-up lever during which the thread take-up lever draws the needle thread with respect to processed fabric to be sewn with the needle thread—controls the needle thread motor in accordance with a torque value in such a way that tension is imparted to the needle thread against a direction in which the thread take-up lever draws the needle thread in accordance with torque data which are generated from embroidery data and whose torque value is specified for each stitch, while the upstream grip section main body is closed and while the downstream grip section main body is opened, thereby imparting rotating force to the turning arm and

that—in a position control zone of control zone for each stitch which is at least a portion of a zone other than the torque control zone achieved while the upstream grip section main body is opened and while the downstream grip section main body is closed—detects at a starting point of the position control zone a current angle position of the needle thread motor which is a rotational position of the needle thread motor while the upstream grip section main body is opened and while the downstream grip section main body is closed, generates angle correspondence data which specify an angle of the needle thread motor from the current angle position to an initial angle position of the needle thread motor for each angle of the main spindle transmitting power to the thread take-up lever, and controls a position of the needle thread motor to its angle corresponding to the angle of the main spindle motor as the angle of the main spindle motor changes as a result of rotation of the main spindle motor in such a way that the angle of the needle thread motor returns to an initial angle position of the needle thread motor, to thus impart rotating force to the turning arm and draw a needle thread from an upstream position.

In a fourth configuration, there is provided a sewing machine comprising: an arm (**312**, **1312**) making up an enclosure of the sewing machine;

a needle bar case (**314**, **1314**) that is provided so as to be slidable in a horizontal direction with respect to the arm and that includes first opening sections (**316***b*, **1342***b*) made at positions between an upstream grip section main body and a downstream grip section main body in a vertical direction such that a leading end of a turning arm of a turning section can be exposed to the front side (or a front side that is on the other side with reference to the arm side), a second opening section (**316***a*, **1342***a*) which is provided above the first opening section and on which an upstream magnet section fronts, and a third opening section (**316***c*, **1342***c*) which is provided below the first opening section and onto which the downstream magnet section fronts; a plurality of thread take-up levers (**12***a*-**1** to **12***a*-**9**) that are provided on a front side of the needle bar case in an exposed fashion and that are provided at downstream positions on needle thread paths with respect to a downstream grip section in a swayable manner; a plurality of needle bars (**12***b*-**1** to **12***b*-**9**) provided in the needle bar case; an upstream grip section (**240**, **1240**) that has the upstream grip section main body (**241**, **1241**) that is placed on a front side of the needle bar case, that pinches to thereby grip the needle thread, and that has upstream first plate-like sections (**242-1** to **242-6**, **1242***a*, **1404**, **1422**) which is formed from a magnetic substance that is a material attracted by the magnet, and which is provided for the respective needle bars and an upstream second plate-like section (**244**, **1244**, **1408**, **1426**) which is provided at back side of the upstream first plate-like sections and on a front side of the second opening section and which is formed from a non-magnetic substance unattracted by the magnet, and an upstream magnet section (**250**, **1250**) that is secured to the arm side and that switches between a closed state in which the needle thread is pinched and gripped between the upstream first plate-like section and the upstream second plate-like section by means of attracting the upstream first plate-like section from a back side of the upstream second plate-like section by means of magnetic force and an open state in which the needle thread is released from the gripped state by canceling attraction caused by magnetic force; the downstream grip section (**260**, **1260**) that is provided at a downstream position along the needle thread path of the upstream grip section and that has a downstream grip section main body (**261**, **1261**) which is placed at a position on a front side of the needle bar case below the upstream grip section main body, which pinches to thereby grip the needle thread, and which has downstream first plate-like sections (**262-1** to **262-6**, **1262***a*, **1414**, **1432**) which is formed from a magnetic substance that is a material attracted by the magnet, and which is provided for the respective needle bars and a downstream second plate-like section (**264**, **1264**, **1418**, and **1436**) which is provided at back side of the downstream first plate-like sections and on a front side of the second opening section and that is formed from a non-magnetic substance unattracted by the magnet, and a downstream magnet section (**270**, **1270**) which is secured to the arm side and which switches between a closed state in which the needle thread is pinched to thereby grip between the downstream first plate-like section and the downstream second plate-like section by means of attracting the downstream first plate-like section from a back side of the downstream second plate-like section by magnetic force and an open state in which the needle thread is released from a gripped state by canceling attraction caused by the magnetic force; needle thread supporting members (**288**, **1288**) that each is provided in the needle bar case and that each supports the needle thread in its horizontal direction at the position of each of the first opening sections (the needle thread supporting members can also be expressed as being provided in the needle bar case and each supporting the needle thread on the front side of each of the first opening sections in the horizontal direction); a turning section (**280**, **1280**) that turns the needle thread existing between the upstream grip section main body and the downstream grip section main body (or "a position on the needle thread located between the upstream grip section main body and the downstream grip section main body") and that has the turning arm (**281**, **1281**) which contacts the needle thread supported by the needle thread supporting member and a needle thread motor (**286**, **1286**) which is secured to the arm side and which turns the turning arm (this can also be expressed as "the turning section contacting the needle thread supported by the needle thread supporting member when the needle thread is turned"); and a control section (**90**), in a control zone for each stitch, that—in a torque control zone including at least a portion of a zone from a bottom dead point to a top dead point of the thread take-up lever during which the thread take-up lever draws the needle thread with respect to processed fabric to be sewn with the needle thread—controls the needle thread motor in accordance with a torque value in such a way that tension is imparted to the needle thread against a direction in which the thread take-up lever draws the needle thread in accordance with torque data which are generated from embroidery data and whose torque value is specified for each stitch, while the upstream grip section main body is closed and while the downstream grip section main body is opened, thereby imparting rotating force to the turning arm in an upward direction and

that—in a position control zone which is at least a portion of a zone other than the torque control zone achieved while the upstream grip section main body is opened and while the downstream grip section main body is closed—detects at a starting point of the position control zone a current angle position of the needle thread motor which is a rotational position of the needle thread motor, generates angle correspondence data which specify an angle of the needle thread motor from the current angle position to an initial angle position (this can also be expressed as an "initial position corresponding to the top dead center of the turning arm") of the needle thread motor for each angle of a main spindle motor representing a rotational position of the main spindle motor (**20**) which rotates a main spindle (**22**) for transmitting power to the thread take-up levers and the needle bars, controls a position of the needle thread motor to its angle corresponding to the angle of the main spindle motor as the angle of the main spindle motor changes as a result of rotation of the main spindle motor in such a way that the angle of the needle thread motor returns to an initial angle position of the needle thread motor, to thus impart rotating force to the turning arm in an upward direction and draw a needle thread from an upstream position, turns the turning arm downward so as to recede to a receded position (this can also be expressed as "the turning arm being turned downwardly and then receded to a receded position") (or as "the turning arm being turned downwardly and then receded to a receded position that is lower than a location where the turning arm contacts the needle thread supported by the needle thread supporting member") when processing proceeds to control of a next stitch and when a needle thread to be selected is changed, and slides the needle bar case, thereby letting the upstream magnet section, the downstream magnet section, and the turning arm come to a position of the selected needle thread.

In the sewing machine having the fourth configuration, a needle thread is subjected to torque control in the torque control zone. Therefore, the magnitude of tension on the needle thread can be controlled. Since the magnitude of tension is controlled in accordance with torque data whose torque values are specified for each stitch, torque control can be performed for each stitch. Consequently, tension on the needle thread can be controlled for each stitch, so that seam hardness can be controlled for each stitch.

In a multi-needle head having a plurality of needle bars, even when a stitch is formed from different needle threads, tension on the needle thread can be equally controlled by means of making torque values in the needle thread control torque data equal. Further, even in the case of a multi-head embroidery sewing machine, needle thread control torque data employed in the torque control zone are made common to the heads, whereby tension on the needle threads exerted by the respective heads can be made equal.

Further, the needle thread control section is provided in place of the tension disc and the rotary tension component in the related-art sewing machine. As a result, in the position control zone where the needle thread is drawn, the upstream grip section main body becomes open. Frictional resistance attributable to the tension disc and the rotary tension component does not exist in an upstream position with respect to the turning arm of the turning section. Further, the downstream grip section main body becomes closed. Consequently, movements of the thread take-up lever will not hinder when the needle thread is drawn; hence, the needle thread can be smoothly drawn from the thread roll, so that the risk of occurrence of a thread break can be made small.

If a break has occurred in the needle thread, the turning arm will not be pulled in a downward direction that is a direction opposite to the direction in which the rotating force of the needle thread motor is imparted when the thread take-up lever moves to its top dead center in the torque control zone. Hence, occurrence of a thread break can be detected by detecting that the turning arm has not turned downwardly. Further, when there are not any thread breaks, the turning arm turns downwardly in the torque control zone. Hence, occurrence of a thread break can be detected accurately.

In the position control zone, a current angle of the needle thread motor is detected, and angle correspondence data for controlling a position of the needle thread motor to its initial angle position are prepared. There is performed control operation for returning the needle thread motor to its initial angle position by means of position control in accordance with the angle correspondence data. In the torque control zone, the needle thread can therefore be drawn by only the amount corresponding to a quantity of thread consumed as a result of pulling of the turning arm, so that an excess or deficiency of the quantity of accumulated thread, which would otherwise be caused by drawing a needle thread, will not occur.

When the structure including the upstream grip section, the downstream grip section, and the turning section is applied to a multi-needle head, the sewing machine can be configured by providing only one each of the upstream magnet section of the upstream grip section, the downstream magnet section of the downstream grip section, and the turning section. Accordingly, the sewing machine can be provided with an efficient structure while its manufacturing cost is curtailed.

In the fourth configuration, the configuration of the needle bar case (**314**, **1314**) can also be embodied as a "needle bar case provided so as to be slidable with respect to the arm. In the needle bar case, first opening sections (**316***b*, **1342***b*) are provided at respective positions between the upstream grip section main body and the downstream grip section main body in the vertical direction on the front side that is opposite to the arm side, in such a way that a leading end of a turning arm of a turning section can be exposed from the interior of the needle bar case. A second opening section (**316***a*, **1342***a*) on that an upstream magnet section fronts is provided at a position above the first opening section. A third opening section (**316***c*, **1342***c*) on that a downstream magnet section fronts is provided at a position below the first opening section." In the fourth configuration, the configuration of the thread take-up lever can also be embodied as a "thread take-up lever (**12***a***-1** to **12***a***-9**) that is provided at a position on the needle bar case below a downstream grip section so as to become exposed to the front side and that permits insertion of the needle thread to be inserted into a sewing needle and that sways around the rotating center."

The fourth configuration can also be modified as follows. Specifically, the sewing machine can also be configured by comprising:

an arm (**312**) making up an enclosure of the sewing machine;

a plurality of thread take-up levers (**12***a*-**1** to **12***a*-**6**) that are provided on the arm, into which needle threads to be inserted into respective sewing needles are inserted, and that sway around a rotating center;

a needle bar case (**314**) that is provided so as to be slidable with respect to the arm and that includes a first opening section (**316***b*) made at positions between an upstream grip section main body and a downstream grip section main body on a front side opposite to the arm side in a vertical direction such that a leading end of a turning arm of a turning section can be exposed from inside of the needle bar case and a second opening section (**316***d*) provided below the downstream grip section main body making up the downstream grip section and on the front side so as to enable the thread take-up lever to be exposed from inside of the needle bar case;

a plurality of needle bars (**12***b*-**1** to **12***b*-**6**) provided in the needle bar case;

an upstream grip section (**240**) including

the upstream grip section main body (**241**) which is placed on a front side of the needle bar case, which pinches to thereby grip the needle thread, and which includes

a plurality of upstream first plate-like sections (**242-1** to **242-6**) formed into a shape of a plate from a magnetic substance that is a material which is attracted by the magnet,

an upstream second plate-like section (**244**) which is placed on a back side of the upstream first plate-like sections and which is formed in the form of the plate from a non-magnetic substance unattracted by the magnet, and

a mounting member (**246**) for attaching in a hanging fashion the upstream first plate-like sections and the upstream second plate-like section to the needle bar case, and

an upstream magnet section (**250**) which is provided on the arm and on a back side of the upstream second plate-like section and which switches between a closed state in which the needle thread is pinched and gripped between the upstream first plate-like sections and the upstream second plate-like section by attracting the upstream first plate-like sections with magnetic force and an open state in which the needle thread is released from a gripped state by canceling magnetic attraction;

a downstream grip section (**260**) placed at a downstream position on the needle thread path of the upstream grip section and including

the downstream grip section main body (**261**) which are placed on the front side of the needle bar case and below the upstream grip section main body, which pinches to thereby grip the needle thread, and which includes

a plurality of downstream first plate-like sections (**262-1** to **262-6**) formed into a shape of a plate from a magnetic substance that is a material which is attracted by a magnet,

a downstream second plate-like section (**264**) which is placed on a back side of the downstream first plate-like sections and which is formed in the form of the plate from a non-magnetic substance unattracted by the magnet, and

a mounting member (**266**) for attaching in a hanging fashion the downstream first plate-like sections and the downstream second plate-like section to the needle bar case, and

a downstream magnet section (**270**) which is placed on the arm facing a back side of the downstream second plate-like section and which switches between a closed state in which the needle thread is pinched and gripped between the downstream first plate-like sections and the downstream second plate-like section by attracting the upstream first plate-like sections with magnetic force and an open state in which the needle thread is released from the gripped state by canceling magnetic attraction;

needle thread supporting members (**288**) which each supports the needle thread on the front side of each of the first opening sections in a horizontal direction when viewed from the front;

the turning section (**280**) which turns a position on the needle thread located between the upstream grip section main body and the downstream grip section main body and which includes

the turning arm (**281**) which contacts the needle thread supported by the needle thread supporting member, and

a needle thread motor (**286**) which is provided on the arm and which turns the turning arm; and

a control section (**90**), in a control zone for each stitch, that—in a torque control zone including at least a portion of a zone from a bottom dead point to a top dead point of the thread take-up lever during which the thread take-up lever draws the needle thread with respect to processed fabric to be sewn with the needle thread controls the needle thread motor in accordance with a torque value in such a way that tension is imparted to the needle thread against a direction in which the thread take-up lever draws the needle thread while the upstream grip section main body is closed and while the downstream grip section main body is opened in accordance with torque data which are prepared from embroidery data and whose torque value is specified for each stitch, thereby imparting rotating force to the turning arm in an upward direction, and that—in a position control zone which is at least a portion of a zone other than the torque control zone achieved while the upstream grip section main body is held in an open state and the downstream grip section main body is held in a closed state detects at a starting point of the position control zone a current angle position of the needle thread motor which is a rotational position of the needle thread motor, generates angle correspondence data which specify an angle of the needle thread motor from a current angle position to an initial angle position of the needle thread motor for each angle of a main spindle motor, i.e., a rotational position of the main spindle motor (**20**) which rotates a main spindle (**22**) for transmitting power to the thread take-up lever and the needle bar, controls the position of the needle thread motor to an angle of the needle thread motor corresponding to the angle of the main spindle motor as an angle of the main spindle motor changes as a result of rotation of the main spindle motor, in such a way that the angle of the needle thread motor returns to the initial angle position of the needle thread motor, thereby imparting rotating force to the turning arm in an upward direction to draw the needle thread from an upstream position, and lets the turning arm recede to a receded position lower than an initial position of the turning arm and the needle bar case slide when processing proceeds to control of a next stitch and when a needle thread to be selected is changed, so that the upstream magnet section, the downstream magnet section, and the turning arm come to a position of the selected needle thread.

In a fifth configuration based on the second or fourth configuration, the sewing machine is characterized in that the needle thread is guided downward after passing through spacing between the upstream first plate-like section and the upstream second plate-like section of the upstream grip section main body, reaches the needle thread supporting member while a path of the needle thread is inverted by a first needle thread path inverting member (**290**, **1290**) provided on the needle bar case, is guided downwardly from the needle thread supporting member and subsequently passes through spacing between the downstream first plate-like section and the downstream second plate-like section in the downstream grip section main body, reaches the thread take-up lever while a path of the needle thread is inverted by a second needle thread path inverting member (**292**, **1337**) provided in the needle bar case, and reaches a sewing needle attached to the needle bar while being guided downward from the thread take-up lever.

In a sixth configuration based on the fifth configuration, the first needle thread path inverting member has a main body section (ga-**1**) having a cylindrical peripheral and a base end section (ga-**2**) which continually extends from a base end of the main body section and which is formed so as to have a diameter smaller than a diameter of the main body section; an indentation section (**1343***b*) used for inserting an end section of the base-end section side of the main body section and a hole section (**1343***a*) which continually extends from the indentation section and which is used for inserting the base end section are formed at positions on the needle bar case where the first needle thread path inverting member and the second needle thread path inverting member are to be attached; the base end section is inserted into the hole section; and an end section of the base-end section side of the main body section is inserted into the indentation section.

Since the ends on the base-end section side of the main body section are inserted and buried in the respective indentation sections, a possibility of the needle thread being caught by spacing between the base end of the main body section and a surface of the needle bar case can be eliminated.

A seventh configuration based on the second, fourth, fifth, or sixth configuration is characterized in that first guide members (**252**, **254**, **1252**, **1254**) set above and below the upstream first plate-like section on the needle bar case are placed at positions that differ from each other in a horizontal direction in the upstream grip section main body; each of the needle thread paths existing between the upstream first plate-like section and the upstream second plate-like section is formed obliquely with respect to a vertical direction; second guide members (**272**, **274**, **1272**, **1274**) set above and below the downstream first plate-like section on the needle bar case are placed at positions that differ from each other in a horizontal direction in the downstream grip section main body; and each of the needle thread paths existing between the downstream first plate-like section and the downstream second plate-like section is formed obliquely with respect to a vertical direction.

In the upstream grip section main body, the needle thread path on the back side of the first plate-like section can be assured in an elongated manner, so that the needle thread can be gripped between the first plate-like section and the second plate-like section more reliably. In the downstream grip section main body, the needle thread path on the back side of the third plate-like section can be assured in an elongated manner, so that the needle thread can be gripped between the third plate-like section and the fourth plate-like section more reliably.

An eighth configuration based on the seventh configuration is characterized in that each of the first guide members and the second guide members has a main body section (ga-**1**) having a cylindrical peripheral and a base end section (ga-**2**) which continually extends from a base end of the main body section and which is formed so as to have a diameter smaller than a diameter of the main body section; an indentation section (**1343***b*) used for inserting an end section of the base-end section side of the main body section and a hole section (**1343***a*) which continually extends from the indentation section and which is used for inserting the base end section are formed at positions on the needle bar case where the first guide members and the second guide members are to be attached; the base end section is inserted into the hole section; and an end section on the base-end section side of the main body section is inserted into the indentation section.

Since the ends on the base-end section side of the main body section are inserted and buried in the respective indentation sections, a possibility of the needle thread being caught by spacing between the base end of the main body section and the surface of the needle bar case can be eliminated.

A ninth configuration based on the second, fourth, fifth, sixth, seventh, or eighth configuration is characterized in that the needle bar case has a needle bar case main body (**1330**) that is provided with the thread take-up levers and the needle bars and that is provided so as to be slidable with respect to the arm and a plate-like plate section (**1341**) provided on an upper surface of the needle bar case main body; and the plate section has the first opening sections, the second opening section, the third opening section, the upstream grip section, the downstream grip section, and the needle thread supporting member.

Therefore, as long as the related-art sewing machine is equipped with the plate section including the first opening sections, the second opening section, the third opening section, the upstream grip section, the downstream grip section, and the needle thread supporting member, in place of the needle thread adjustment member mount section having the tension disc and the rotary tension component, the configuration of the related-art sewing machine can be utilized. Hence, manufacturing cost can be curtailed.

A tenth configuration based on the second, fourth, fifth, sixth, seventh, eighth, or ninth configuration is characterized in that a magnet section/motor supporting member (**1360**) that supports the upstream magnet section, the downstream magnet section, and the needle thread motor, and is secured to the arm.

An eleventh configuration based on the second, fourth, fifth, sixth, seventh, eighth, or ninth configuration is characterized by further comprising a magnet section/motor supporting member (**1370**) that supports the upstream magnet section, a downstream magnet section, and the needle thread motor, and a sliding support member (**1350**, **1352**) that is provided in the needle bar case and that slidably supports the magnet section/motor supporting member in a horizontal direction when viewed from the front, and a slide regulation member (**1380**) that is secured to the arm and that regulates horizontal sliding action of the magnet section/motor supporting member, to thus horizontally position the supporting member; and the upstream magnet section, the downstream magnet section, and the needle thread motor are fixedly provided on the arm side as a result of horizontal sliding action of the magnet section/motor supporting member being regulated by the slide regulation member.

In the eleventh configuration, when the magnet section/motor supporting member is attached to the sewing machine, the magnet section/motor supporting member is adjusted to an appropriate position while being slid along the sliding support member, the slide regulation member regulates horizontal sliding action of the magnet section/motor supporting member, whereby the upstream magnet section, the downstream magnet section, and the needle thread motor are secured to the arm side. Therefore, horizontal positions of the magnet section/motor supporting member can be finely adjusted, and horizontal positions of the upstream magnet section, the downstream magnet section, and the turning arm can be finely adjusted.

Moreover, a twelfth configuration based on the second, fourth, fifth, sixth, seventh, eighth, ninth, tenth, or eleventh configuration is characterized by further comprising an upstream first plate-like section supporting members (**1401**) that each has a first shaft section (**1401***c*) to be inserted into a hole section of the upstream first plate-like section (**1404**) and that is provided on a front side of the needle bar case, an upstream coiled springs (**1402**) into each of which the first shaft section is to be inserted, and an upstream protective plate-like sections (**1406**) that each is secured to a leading end of the first shaft section and that is formed from a non-magnetic substance unattracted by the magnet, wherein the upstream first plate-like section is provided with the hole section used for inserting the first shaft section; the upstream second plate-like section remains in contact with a surface of the upstream protective plate-like section that is on the other side with respect to the upstream first plate-like section; the upstream first plate-like section is provided between the upstream coiled spring and the upstream protective plate-like section while the first shaft section remains inserted into the hole section; and the upstream first plate-like section is driven toward the upstream protective plate-like section by means of the upstream coiled spring; and

further comprising a downstream first plate-like section supporting members (**1411**) that each has a second shaft section (**1411***c*) to be inserted into the hole section of a downstream first plate-like section (**1414**) and that is provided on a front side of the needle bar case, a downstream coiled springs (**1412**) into each of which the second shaft section is to be inserted, and a downstream protective plate-like sections (**1416**) that each is secured to a leading end of the second shaft section and that is formed from a non-magnetic substance unattracted by the magnet, wherein

the downstream first plate-like section is provided with the hole section used for inserting the second shaft section; the downstream second plate-like section remains in contact with a surface of the downstream protective plate-like section that is on the other side with respect to the downstream first plate-like section; the downstream first plate-like section is provided between the downstream coiled spring and the downstream protective plate-like section while the second shaft section remains inserted into the hole section; and the downstream first plate-like section is driven toward the downstream protective plate-like section by means of the downstream coiled spring.

Therefore, the upstream first plate-like section and the upstream protective plate-like section are driven toward the upstream second plate-like section by means of the upstream coiled spring. Even when the upstream first plate-like section is unattracted by the upstream magnet section, the upstream first plate-like section remains in contact with the upstream protective plate-like section, and the upstream protective plate-like section remains in contact with the upstream second plate-like section. Accordingly, vibration sound, which would otherwise arise as a result of repeated opening/closing of the upstream grip section main body or as a result of vibration of a head, can be prevented. Likewise, the downstream first plate-like section and the downstream protective plate-like section are driven toward the downstream second plate-like section by means of the downstream coiled spring. Even when the downstream first plate-like section is unattracted by the downstream magnet section, the downstream first plate-like section remains in contact with the downstream protective plate-like section, and the downstream protective plate-like section remains in contact with the downstream second plate-like section. Accordingly, vibration sound, which would otherwise arise as a result of repeated opening/closing of the downstream grip section main body or as a result of vibration of a head, can be prevented.

The upstream protective plate-like section (the downstream protective plate-like section) is interposed between the upstream second plate-like section (the downstream second plate-like section) and the needle thread. Therefore, abrasion of the upstream second plate-like section (the downstream second plate-like section), which would otherwise be caused as a result of the needle thread contacting the upstream second plate-like section (the downstream second plate-like section), can be prevented.

A thirteenth configuration based on the second, fourth, fifth, sixth, seventh, eighth, ninth, tenth, or eleventh configuration is characterized by further comprising an upstream sliding members (**1421**) that each is inserted into a position above the second opening section on the needle bar case and that each is provided so as to be slidable along a direction of an axis line of the upstream sliding member and an upstream driving members (**1424**) that each drives upstream sliding member to a back side of the needle bar case, wherein the upstream first plate-like section (**1422**) is provided while hanging on the upstream sliding member, and an upstream press operation member (**1362**) for pressing the upstream sliding member corresponding to the upstream first plate-like section which is attracted by the upstream magnet section in a direction opposite to a driving direction of the upstream driving member is provided on the arm side; and further comprising a downstream sliding members (**1431**) that each is inserted into a position above the third opening section on the needle bar case and that each is provided for each of the upstream first plate-like sections so as to be slidable in an axial direction of the downstream sliding member and a downstream driving members (**1434**) that each drives the downstream sliding member to the back side of the needle bar case, wherein the downstream first plate-like section (**1432**) is provided while hanging on the downstream sliding member, and a downstream press operation member (**1364**) for pressing the downstream sliding member corresponding to the downstream first plate-like section which is attracted by the downstream magnet section in a direction opposite to a driving direction of the downstream driving member is provided on the arm side.

Consequently, the upstream first plate-like sections corresponding to the needle bars other than the selected needle bar are pressed toward the upstream second plate-like section. Hence, sound, which would otherwise occur when the upstream first plate-like sections contacting the upstream second plate-like section, does not arise, nor does vibration sound attributable to head vibration arise. Moreover, since the upstream first plate-like section corresponding to the selected needle bar is not pressed to the back side by the upstream press operation member, so that the needle thread can be sufficiently released from a gripped state. Likewise, the downstream first plate-like sections corresponding to the needle bars other than the selected needle bar are pressed toward the downstream second plate-like section. Hence, sound, which would otherwise occur when the downstream first plate-like sections contacting the downstream second plate-like section, does not arise, nor does vibration sound attributable to head vibration arise. Moreover, since the downstream first plate-like section corresponding to the selected needle bar is not pressed to the back side by the downstream press operation member, so that the needle thread can be sufficiently released from a gripped state.

A fourteenth configuration is characterized by a sewing machine comprising: an arm (**1312**) making up an enclosure of the sewing machine; a needle bar housing case (**1330**) that is disposed so as to be slidable in a horizontal direction with respect to the arm and that houses a plurality of needle bars (**12***b*-**1** to **12***b*-**9**); a tabular plate section (**1341**) that is disposed on an upper surface of the needle bar housing case and that is provided with first opening sections (**1342***b*) placed at positions between an upstream grip section main body and a downstream grip section main body in a vertical direction such that a leading end of a turning arm of a turning section can be exposed to the front side (or a "front side opposite to the arm side"), a second opening section (**1342***a*) which is provided above the respective first opening sections and on which an upstream magnet section fronts, and a third opening section (**1342***c*) that is provided below the first opening section and on which a downstream magnet section fronts; a plurality of thread take-up levers (**12***a*-**1** to **12***a*-**9**) that are axially supported by the needle bar housing case in a swayable manner, that are provided on a front side of the needle bar housing case in an exposed fashion, and that are provided at downstream positions on needle thread paths with respect to a downstream grip section; an upstream grip section (**1240**) that has the upstream grip section main body (**1241**) that is placed on a front side of the plate section, that pinches to thereby grip a needle thread, and has upstream first plate-like sections (**1242***a*, **1404**, **1422**) which is formed from a magnetic substance that is a material attracted by the magnet, and which is provided for the respective needle bars, and an upstream second plate-like section (**1244**, **1408**, **1426**) which is placed on a front side of the second opening section while facing a back side of the upstream first plate-like section and which is formed from a non-magnetic substance unattracted by the magnet, and the upstream magnet section (**1250**) that is secured to the arm side and that switches between a closed state in which the needle thread is pinched and gripped between the upstream first plate-like section and the upstream second plate-like section by means of attracting the upstream first plate-like section from a back side of the upstream second plate-like section by magnetic force and an open state in which the needle thread is released from the gripped state by canceling attraction caused by magnetic force; the downstream grip section (**1260**) that is placed at a downstream position along a needle thread path of the upstream grip section and has a downstream grip section main body (**1261**) which is placed below the upstream grip section main body on a front side of the plate section, which pinches to thereby grip the needle thread, and which has downstream first plate-like sections (**1262***a*, **1414**, **1432**) which is formed from a magnetic substance that is a material attracted by a magnet and which is provided for respective needle bars, and a downstream second plate-like section (**1264**, **1418**, **1436**) which is placed on a front side of the second opening section while facing a back side of the downstream first plate-like section and formed from a non-magnetic substance unattracted by the magnet, and the downstream magnet section (**1270**) which is secured to the arm side and which switches between a closed state in which the needle thread is pinched and gripped between the downstream first plate-like section and the downstream second plate-like section by means of attracting the downstream first plate-like section from a back side of the downstream second plate-like section by magnetic force and an open state in which the needle thread is released from a gripped state by canceling attraction caused by the magnetic force; needle thread supporting members (**1288**) (this can also be expressed as a "needle thread supporting members that each is placed on the plate section and supports the needle thread on the front side of each of the first opening sections and in the horizontal direction") that each is provided in the plate section and that each supports the needle thread in its horizontal direction at the position of each of the first opening sections; the turning section (**1280**) that turns the needle thread existing between the upstream grip section main body and the downstream grip section main body (this can also be expressed as "a position on the needle thread existing between the upstream grip section main body and the downstream grip section main body") and that has the turning arm (**1281**) which contacts the needle thread supported by the needle thread supporting member and a needle thread motor (**1286**) which is secured to the arm side and which turns the turning arm (this can also be expressed as a "turning arm that contacts a needle thread supported by the needle thread supporting member when the needle thread is turned"); and a control section (**90**), min a control zone for each stitch, that—in a torque control zone including at least a portion of a zone from one dead point to another dead point of the thread take-up lever during which the thread take-up lever draws the needle thread with respect to processed fabric to be sewn with the needle thread—controls the needle thread motor in accordance with a torque value in such a way that tension is imparted to the needle thread against a direction in which the thread take-up lever draws the needle thread in accordance with torque data which are generated from embroidery data and whose torque value is specified for each stitch, while the upstream grip section main body is closed and while the downstream grip section main body is opened, thereby imparting rotating force to the turning arm in an upward direction, and that in a position control zone which is at least a portion of a zone other than the torque control zone achieved while the upstream grip section main body is opened and while the downstream grip section main body is closed—detects at a starting point of the position control zone a current angle position of the needle thread motor which is a rotational position of the needle thread motor, generates angle correspondence data which specify an angle of the needle thread motor from the current angle position to an initial angle position of the needle thread motor (this can also be expressed as an "initial position that is one corresponding to the top dead center of the turning arm") for each angle of a main spindle motor (**20**) representing a rotational position of the main spindle motor which rotates a main spindle (**22**) for transmitting power to the thread take-up lever and the needle bar, controls a position of the needle thread motor to its angle corresponding to the angle of the main spindle motor as the angle of the main spindle motor changes as a result of rotation of the main spindle motor in such a way that the angle of the needle thread motor returns to an initial angle position of the needle thread motor, to thus impart rotating force to the turning arm in an upward direction and draw a needle thread from an upstream position, turns the turning arm downward so as to recede to a receded position (this can also be expressed as "the turning arm is turned and receded to a lower receded position") (or "the turning arm is turned downward so as to recede to a receded position located below a position where the turning arm contacts the needle thread supported by the needle thread supporting member") when processing proceeds to control of a next stitch and when a needle thread to be selected is changed, and slides the needle bar housing case, thereby letting the upstream magnet section, the downstream magnet section, and the turning arm come to a position of the selected needle thread.

In the sewing machine having the fourteenth configuration, a needle thread is subjected to torque control in the torque control zone. Therefore, a magnitude of tension on the needle thread can be controlled. Since the magnitude of tension is controlled according to torque data whose torque value is specified for each stitch, torque control can be performed for each stitch. The tension on the needle thread can be controlled for each stitch, so that seam hardness can be controlled on a per-stitch basis.

In a multi-needle head having a plurality of needle bars, even when a stitch is formed from different needle threads, tension on the needle thread can be equally controlled by means of making torque values in the needle thread control torque data equal to each other. Further, even in the case of a multi-head embroidery sewing machine, the needle thread control torque data employed in the torque control zone are made common to the heads, whereby tension on the needle threads exerted by the respective heads can be made equal.

Further, the needle thread control section is provided in place of the tension disc and the rotary tension component in the related-art sewing machine. As a result, in the position control zone where the needle thread is drawn, the upstream grip section main body becomes open. Frictional resistance attributable to the tension disc and the rotary tension component does not exist in an upstream position with respect to the turning arm of the turning section. Further, the downstream grip section main body becomes closed. Consequently, movements of the thread take-up lever will not hinder when the needle thread is drawn; hence, the needle thread can be smoothly drawn from the thread roll, so that the risk of occurrence of a thread break can be made small.

If a break has occurred in the needle thread, the turning arm will not be pulled, in a downward direction that is a direction opposite to the direction in which the rotating force of the needle thread motor is imparted when the thread take-up lever moves to its top dead center in the torque control zone. Hence, occurrence of a thread break can be detected by detecting that the turning arm does not turn downwardly. Further, when there are not any thread breaks, the turning arm turns downwardly in the torque control zone. Hence, occurrence of a thread break can be detected accurately.

In the position control zone, a current angle of the needle thread motor is detected, and angle correspondence data used for controlling the position of the needle thread motor to its initial angle position are generated. There is performed control operation for returning the needle thread motor to its initial angle position by means of position control in accordance with the angle correspondence data. In the torque control zone, the needle thread can therefore be drawn by only the amount corresponding to a quantity of thread consumed as a result of pulling of the turning arm, so that an excess or deficiency of the quantity of accumulated thread, which would otherwise be caused by drawing a needle thread, will not occur.

When the structure including the upstream grip section, the downstream grip section, and the turning section is applied to a multi-needle head, the sewing machine can be configured by providing only one each of the upstream magnet section of the upstream grip section, the downstream magnet section of the downstream grip section, and the turning section. Accordingly, the sewing machine can be provided with an efficient structure while its manufacturing cost is curtailed.

In the fourteenth configuration, the thread take-up lever can also be implemented as "a plurality of thread take-up levers (**12***a***-1** to **12***a***-9**) that are provided in the needle bar housing case in a swayable manner so as to be exposed to the front from positions below the downstream grip section and that permit insertion of needle threads to be inserted into respective sewing needles."

In the second, fourth, and fourteenth configurations, the upstream first plate-like section is preferably placed in such a way that spacing between the upstream first plate-like section and the upstream second plate-like section becomes variable, and the downstream first plate-like section is preferably placed in such a way that spacing between the downstream first plate-like section and the downstream second plate-like section becomes variable. In the second, fourth, and fourteenth configuration, the needle thread supporting member is provided in a one-to-one correspondence with the needle thread. Each of the needle thread supporting members includes a first circular-arc member formed approximately concentrically with the rotating center of the needle thread motor; a second circular-arc member formed, on the other side with respect to the axis line of the output shaft, approximately concentrically with the rotating center of the needle thread motor while spaced apart from the first circular-arc member; and a connecting member for connecting a lower end of the first circular-arc member to a lower end of the second circular-arc member. Specifically, the pair of needle thread supporting members is preferably placed while spaced apart from each other in the horizontal direction.

A configuration **14-1** based on the fourteenth configuration can also be characterized in that the needle thread is guided downward after passing through spacing between the upstream first plate-like section and the upstream second plate-like section of the upstream grip section main body, reaches the needle thread supporting member while a path of the needle thread is inverted by a first needle thread path inverting member (**1290**) provided on the plate section, is guided downwardly from the needle thread supporting member and subsequently passes through spacing between the downstream first plate-like section and the downstream second plate-like section in the downstream grip section main body, reaches the thread take-up lever while a path of the needle thread is inverted by a second needle thread path inverting member (**1292**) provided in the needle bar case, and reaches a sewing needle attached to the needle bar while being guided downward from the thread take-up lever.

A configuration **14-2** based on the configuration **14-1** can also be characterized in that the first needle thread path inverting member has a main body section (ga-**1**) having a cylindrical peripheral and a base end section (ga-**2**) which continually extends from a base end of the main body section and which is formed so as to have a diameter smaller than a diameter of the main body section and that an indentation section (**1343***b*) used for inserting an end of the base-end section side of the main body section and a hole section (**1343***a*) which continually extends from the indentation section and which is used for inserting the base end section are formed at positions on the plate section where the first needle thread path inverting member and the second needle thread path inverting member are to be attached; and that the base end section is inserted into the hole section; and that an end section on the base-end section side of the main body section is inserted into the indentation section.

A configuration **14-3** based on the configuration **14**, **14-1**, or **14-2** can also be characterized in that a mounting member is attached to a substantial center of the upper area of the upstream first plate-like section of the upstream grip section main body in its horizontal direction; that the first guide members (**1252**, **1254**) set above and below the upstream first plate-like section on the plate section are placed at positions that differ from each other in the horizontal direction in the upstream grip section main body; that each of the needle thread paths existing between the upstream first plate-like section and the upstream second plate-like section is formed obliquely with respect to a vertical direction; that second guide members (**1272**, **1274**) set above and below the downstream first plate-like section on the plate section are placed at positions that differ from each other in the horizontal direction in the downstream grip section main body; and that each of the needle thread paths existing between the downstream first plate-like section and the downstream second plate-like section is formed obliquely with respect to the vertical direction.

A configuration **14-4** based on the configuration **14-3** can also be characterized in that each of the first guide members and the second guide members has a main body section (ga-**1**) having a cylindrical peripheral and a base end section (ga-**2**) which continually extends from a base end of the main body section and which is formed so as to have a diameter smaller than a diameter of the main body section and that an indentation section (**1343***b*) used for inserting an end section of the base-end section side of the main body section and a hole section (**1343***a*) which continually extends from the indentation section and which is used for inserting the base end section are formed at positions on the needle bar case where the first guide members and the second guide members are to be attached; and that the base end section is inserted into the hole section; and that an end section on the base-end section side of the main body section is inserted into the indentation section.

A configuration **14-5** based on the fourteenth configuration, the configuration **14-1**, the configuration **14-2**, the configuration **14-3**, or the configuration **14-4** can also be characterized in that a magnet section/motor supporting member (**1360**) that supports the upstream magnet section, the downstream magnet section, and the needle thread motor is secured to the arm.

A configuration **14-6** based on the fourteenth configuration, the configuration **14-1**, the configuration **14-2**, the configuration **14-3**, or the configuration **14-4** can also be characterized by further comprising a magnet section/motor supporting member (**1370**) that supports the upstream magnet section, the downstream magnet section, and the needle thread motor and a sliding support member (**1350**, **1352**) that is provided in the plate section and/or the needle bar housing case and that slidably supports the magnet section/motor supporting member so as to be slidable in a horizontal direction when viewed from the front, and a slide regulation member (**1380**) that is secured to the arm and that regulates horizontal sliding action of the magnet section/motor supporting member, to thus horizontally position the magnet section/motor supporting member, wherein the upstream magnet section, the downstream magnet section, and the needle thread motor are fixedly provided on an arm side as a result of horizontal sliding action of the magnet section/motor supporting member being regulated by the slide regulation member.

A configuration **14-7** based on the fourteenth configuration, the configuration **14-1**, the configuration **14-2**, the configuration **14-3**, the configuration **14-4**, the configuration **14-5**, or the configuration **14-6** can also be characterized by further comprising an upstream first plate-like section supporting members (**1401**) that each is provided on a front side of the plate section and that has a first shaft section to be inserted into a hole section of the upstream first plate-like section and, an upstream coiled springs (**1402**) into each of which the first shaft section is to be inserted, and an upstream protective plate-like sections (**1406**) that each is secured to a leading end of the first shaft section and that is formed from a non-magnetic substance unattracted by the magnet, wherein the upstream first plate-like section is provided with the hole section used for inserting the first shaft section; the upstream second plate-like section remains in contact with a surface of the upstream protective plate-like section that is on the other side with respect to the upstream first plate-like section; the upstream first plate-like section is provided between the upstream coiled spring and the upstream protective plate-like section while the first shaft section remains inserted into the hole section; and the upstream first plate-like section is driven toward the upstream protective plate-like section by means of the upstream coiled spring; and further comprising a downstream first plate-like section supporting members (**1411**) that each has a second shaft section which is provided on a front side of the needle bar case and which is to be inserted into a hole section of a downstream first plate-like section, a downstream coiled springs (**1412**) into each of which the second shaft section is to be inserted, and a downstream protective plate-like sections (**1416**) that each is secured to a leading end of the second shaft section and that is formed from a non-magnetic substance unattracted by the magnet, wherein the downstream first plate-like section is provided with the hole section used for inserting the second shaft section; the downstream second plate-like section remains in contact with a surface of the downstream protective plate-like section that is on the other side with respect to the downstream first plate-like section; the downstream first plate-like section is provided between the downstream coiled spring and the downstream protective plate-like section while the second shaft section remains inserted into the hole section; and the downstream first plate-like section is driven toward the downstream protective plate-like section by means of the downstream coiled spring.

A configuration **14-8** based on the fourteenth configuration, the configuration **14-1**, the configuration **14-2**, the configuration **14-3**, the configuration **14-4**, the configuration **14-5**, or the configuration **14-6** can also be characterized by further comprising an upstream sliding members (**1421**) that each is inserted into a position above the second opening section on the plate section and that each is provided so as to be slidable along a direction of an axis line of the upstream sliding member and an upstream driving members (**1424**) that each drives the upstream sliding member to a back side of the plate section, wherein the upstream first plate-like section is provided while hanging on the upstream sliding member, and an upstream press operation member (**1362**) for pressing the upstream sliding member corresponding to the upstream first plate-like section which is attracted by the upstream magnet section in a direction opposite to a driving direction of the upstream driving member is provided on the arm side; and further comprising a downstream sliding members (**1431**) that each is inserted into a position above the third opening section on the plate section and that each is provided for each of the upstream first plate-like sections so as to be slidable in an axial direction of the downstream sliding member and a downstream driving members (**1434**) that each drives the downstream sliding member to the back side of the plate section, wherein the downstream first plate-like section is provided while hanging on the downstream sliding member, and a downstream press operation member (**1364**) for pressing the downstream sliding member corresponding to the downstream first plate-like section which is attracted by the downstream magnet section in a direction opposite to a driving direction of the downstream driving member is provided on the arm side.

A fifteenth configuration based on the second configuration, the fourth configuration, the fifth configuration, the sixth configuration, the seventh configuration, the eighth configuration, the ninth configuration, the tenth configuration, the eleventh configuration, the twelfth configuration, the thirteenth configuration, or the fourteenth configuration can also be characterized in that the needle thread supporting member supports a needle thread on the front side of the first opening sections.

A sixteenth configuration based on the third configuration, the fourth configuration, or the fourteenth configuration can also be characterized in that during torque control performed in the torque control zone, a value of a torque deviation is calculated from a torque value in the torque data and a torque value based on a current value fed to the needle thread motor during torque control performed in the torque control zone, and an electric current is fed to the needle thread motor in accordance with the calculated torque deviation.

A seventeenth configuration based on the third configuration, the fourth configuration, the fourteenth configuration, or the sixteenth configuration can also be characterized by further comprising a motor angle detection section for detecting a rotational position of the needle thread motor, wherein position control is performed during position control performed in the position control zone along operation control steps including: a reading step of reading an angle of the needle thread motor from the angle correspondence data during position control performed in the position control zone, a speed data calculation step of calculating an amount of change per unit time in angle data read in the reading step, to thus calculate speed data, a torque data calculation step of detecting an amount of change per unit time in the speed data calculated in the speed data calculation step, to thus calculate torque data; a location deviation calculation step of calculating a value of a location deviation from the angle data read in the reading step and the motor angle data read by the motor angle detecting section, a speed deviation calculation step of calculating a value of a speed deviation from the calculated value of the location deviation, the calculated speed data, and the amount of change per unit time in motor angle detected by the angle detection section, a torque deviation calculation step of calculating a value of a torque deviation from the calculated value of the speed deviation, the calculated torque data, and a value of torque based on a current value fed to the motor, and a current feeding step of feeding an electric current to the motor in accordance with the calculated value of the toque deviation.

An eighteenth configuration based on any one of the first configuration to the seventeenth configuration is characterized in that the control section detects a main spindle angle in accordance with zone data in which a starting point and an end point of the torque control zone and a starting point and an end point of the position control zone are specified as information about a main spindle angle that is a rotational position of the main spindle motor, thereby determining the torque control zone and the position control zone.

A nineteenth configuration based on any one of the first configuration to the eighteenth configuration is characterized in that the starting point of the position control zone corresponds to any location in a zone from the other dead point to the one dead point of the thread take-up lever and is in front of a top dead point of a shuttle, and the end point of the position control zone corresponds to any location in a zone from the one dead point to the other dead point of the thread take-up lever.

A twentieth configuration based on any one of the first configuration to the nineteenth configuration is characterized in that a zone in which an electric current is not fed to the needle thread motor is set between the end point of the torque control zone and the starting point of the position control zone; a zone during which an electric current is not fed to the needle thread motor is set between the end point of the position control zone and the starting point of the torque control zone; the upstream grip section main body is switched to a closed state, and the downstream grip section main body is switched to an open state at the end point of the position control zone; and the upstream grip section main body is switched to the open state, and the downstream grip section main body is switched to a closed state at the end point of the torque control zone. Specifically, a current supply halt time is set in order to perform switching between torque control and position control after switching between opening and closing of the upstream grip section main body and switching between opening and closing of the downstream grip section main body have been performed without fail. In each of the configurations, the magnet section is specifically an electromagnet.

Advantages of the Invention

In the sewing machine of the present invention, a needle thread is subjected to torque control in the torque control zone. Therefore, the magnitude of tension on the needle thread can be controlled. Since torque values are specified for each stitch, torque can be controlled for each stitch. Consequently, tension on the needle thread can be controlled for each stitch, so that seam hardness can be controlled for each stitch.

Even in the case of a multi-needle head or when a stitch is formed from different needle threads, tension on the needle thread can be equally controlled by means of making torque values equal to each other. Further, even in the case of a multi-head embroidery sewing machine, torque values employed in the torque control zone are made common to the heads, whereby tension on the needle threads exerted by the respective heads can be made equal.

Further, the needle thread control section is provided in place of the tension disc and the rotary tension component in the related-art sewing machine. As a result, in the position control zone where the needle thread is drawn, the upstream grip section main body becomes open. Frictional resistance attributable to the tension disc and the rotary tension component does not exist in an upstream position with respect to the turning arm of the turning section. Further, since the downstream grip section main body becomes closed, movements of the thread take-up lever will not pose any problem when the needle thread is drawn. Consequently, the needle thread can be smoothly drawn from the thread roll, so that the risk of occurrence of a thread break can be made small.

If a break has occurred in the needle thread, the turning arm will not be pulled, in the torque control zone, in a direction that is a direction opposite to the direction in which the rotating force of the needle thread motor is imparted when the thread take-up lever moves to its top dead center. Hence, occurrence of a thread break can be detected by detecting that the turning arm does not turn in the direction opposite to the direction in which the rotating force of the needle thread motor is imparted. Further, when there are not any thread breaks, the turning arm turns, in the torque control zone, in the direction opposite to the direction in which the needle thread motor imparts rotating force. Hence, occurrence of a thread break can be detected accurately.

In the position control zone, rotating force is imparted to the turning arm in accordance with angle position data pertaining to the needle thread motor such that the angle of the needle thread motor returns to its initial angle position which is a rotational position of the needle thread motor. Hence, the needle thread can be drawn by only the amount corresponding to a quantity of thread consumed as a result of the turning arm having been pulled in the direction opposite to the direction in which the rotating force of the needle thread motor is imparted. Therefore, an excess or deficiency of the quantity of accumulated thread, which would otherwise be caused by drawing a needle thread, will not occur.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** It is an explanatory view showing a configuration of a sewing machine of a first embodiment.

FIG. **2** It is an explanatory view of a principal part of the sewing machine of the first embodiment.

FIG. **3** It is a perspective view of the sewing machine of the first embodiment.

FIG. **4** It is a left side elevation view of the sewing machine of the first embodiment.

FIG. **5** It is an explanatory view of a principal part of the sewing machine of the first embodiment.

FIG. **6** It is an explanatory view showing a configuration of zone position data.

FIG. **7** It is an explanatory view showing main spindle data.

FIG. **8** It is an explanatory view showing the main spindle data.

FIG. **9** It is an explanatory view showing needle thread control torque data.

FIG. **10** It is a flowchart showing operation of a needle thread motor.

FIG. **11** It is a flowchart showing a method for controlling the needle thread motor and, particularly, a flowchart showing a torque control method.

FIG. **12** It is a flowchart showing the method for controlling the needle thread motor and, particularly, a flowchart showing a position control method.

FIG. **13** It is a flowchart showing the method for controlling the needle thread motor and, particularly, a flowchart showing the position control method.

FIG. **14** It is an explanatory view illustrating a method for controlling a position of the needle thread motor.

FIG. **15** It is an explanatory view showing angle correspondence data.

FIG. **16** It is a functional section diagram showing a method for controlling the needle thread motor.

FIG. **17** It is a flowchart showing operation of an upstream grip section and operation of a downstream grip section.

FIG. **18** It is an explanatory view showing operation of the sewing machine of the first embodiment and operation of a sewing machine of a second embodiment.

FIG. **19** It is an explanatory view for describing operation of a needle thread control section.

FIG. **20** It is an explanatory view showing operation of the sewing machine of the first embodiment and operation of the sewing machine of the second embodiment.

FIG. **21** It is a flowchart showing a method for controlling a main spindle motor.

FIG. **22** It is a subsequent flowchart showing the method for controlling the main spindle motor.

FIG. **23** It is a functional section diagram showing the method for controlling the main spindle motor.

FIG. **24** It is an explanatory view of a principal part showing another example sewing machine of the first embodiment.

FIG. **25** It is an explanatory view showing the sewing machine of the second embodiment.

FIG. **26** It is a front view showing the sewing machine of the second embodiment.

FIG. **27** It is a fragmentary right-side cross sectional view showing the sewing machine of the second embodiment.

FIG. **28** It is a perspective view of a principal part showing the sewing machine of the second embodiment.

FIG. **29** It is an explanatory view showing a sewing machine of a third embodiment.

FIG. **30** It is a forward perspective view showing a head of the sewing machine of the third embodiment.

FIG. **31** It is a backward perspective view showing the head of the sewing machine of the third embodiment.

FIG. **32** It is a front view showing a principal part of the head of the sewing machine of the third embodiment.

FIG. **33** It is a fragmentary left-side cross sectional view showing the head of the sewing machine of the third embodiment.

FIG. **34** It is an enlarged view of the principal part shown in FIG. **32**.

FIG. **35** It is a fragmentary left-side cross sectional view showing the head of the sewing machine of the third embodiment.

FIG. **36** It is a backward perspective view of a first plate-like member.

FIG. **37** It is a backward perspective view showing a head of a sewing machine of a fourth embodiment.

FIG. **38** It is a fragmentary left-side cross sectional view showing a principal part of the head of the sewing machine of the fourth embodiment.

FIG. **39** It is a fragmentary left-side cross sectional view showing a principal part of a head of a sewing machine of a fifth embodiment.

FIG. **40** It is an exploded perspective view showing a grip section main body of the sewing machine of the fifth embodiment.

FIG. **41** It is a front view of a principal part showing the grip section main body of the sewing machine of the fifth embodiment.

FIG. **42** It is a fragmentary left-side cross sectional view showing a principal part of a head of a sewing machine of a sixth embodiment.

FIG. **43** It is an exploded perspective view showing a grip section main body and a projecting member of the sewing machine of the sixth embodiment.

FIG. **44** It is an end view showing operation of the sewing machine of the sixth embodiment.

FIG. **45** It is a front view of a principal part showing the grip section main body of the sewing machine of the sixth embodiment.

FIG. **46** It is an explanatory view showing configurations of a guide member and ways to attach the same.

FIG. **47** It is an explanatory view showing a related-art sewing machine.

FIG. **48** It is a forward perspective view showing the related-art sewing machine.

EMBODIMENTS FOR IMPLEMENTING THE INVENTION

In the present invention, a magnitude of tension on a needle thread can be controlled. In particular, the magnitude of tension imparted to the needle threads when thread take-up levers are upwardly actuated can be controlled. Further, solution of drawbacks; namely, providing a needle thread tension controller that does not cause an excess or deficiency of the quantity of accumulated thread, which would otherwise be caused by drawing a needle thread, is realized as follows.

First Embodiment

A sewing machine **5** described in connection with a first embodiment of the present invention is constituted as shown in FIGS. **1** through **5**. The sewing machine **5** has a head **7**, a shuttle **12***c*, a sewing frame (also called a "holding frame" or "embroidery frame") **12***d*, a frame actuator **24**, and a memory device **92**. FIG. **2** is a drawing conceptually showing a principal part of the sewing machine **5**. FIG. **3** specifically shows details of FIG. **2**.

The head **7** is positioned above an approximately tabular sewing machine table (not shown). A frame **120** (see FIGS. **3** and **4**) stands upright on an upper surface of the sewing machine table, and the head **7** is put on a front side (a **Y1** side) of the frame **120**.

The head **7** is constituted as shown in FIG. **1**, FIG. **3**, and FIG. **4** and includes a machine element group **10**, a main spindle motor **20**, a main spindle **22**, a needle thread control section **30**, a control circuit **90**, a pretension component **96**, and a thread roll **98** wound around a needle thread bobbin, and a case **110**.

The machine element group **10** is comprised of machine elements actuated in the head **7**. A thread take-up lever **12***a*, a needle bar **12***b*, and a presser foot (not shown) are provided as the machine elements. The respective machine elements, such as the thread take-up lever **12***a*, the needle bar **12***b*, and the presser foot, and the shuttle **12***c* are actuated by transmitting rotating force of the main spindle **22** byway of power transmission means, like a cam mechanism or a belt mechanism, as in the case of the related-art sewing machine. Specifically, as shown in FIG. **18**, the position of the thread take-up lever **12***a*, the position of the needle bar **12***b*, and the position of the shuttle **12***c* (a position between a top dead center and a bottom dead center) are specified according to a spindle angle (i.e., a rotational position of the main spindle **22**); to be exact, an angle of the main spindle motor **20** (specifically, a rotational position of the main spindle motor **20**).

The thread take-up lever **12***a* is formed so as to be able to sway around an axis line in a horizontal direction (a direction **X1**-**X2**) with respect to the case **110**. The thread take-up lever **12***a* turns between a bottom dead center (one dead center) and a top dead center (the other dead center). Specifically, the thread take-up lever **12***a* is axially supported by the case **110** so as to sway around a rotating center (that can also be referred to as a swaying center) **12***ab*. A needle thread to be inserted into a sewing needle **12***ba* is inserted into the thread take-up lever **12***a*.

The needle bar **12***b* is also provided so as to be movable in the vertical direction. The sewing needle **12***ba* (a needle thread is inserted into a pin hole **12***bb* of the sewing needle **12***ba*) is fixedly provided at a lower end of the needle bar **12***b*. A needle bar connecting stud **14***a* is fixedly provided at an upper end of the needle bar **12***b*. Further, a needle bar actuation member **14***b* is engaged with the needle bar connecting stud **14***a*. A base needle bar **14***c* positioned in the vertical direction is inserted into the needle bar actuation member **14***b*. The needle bar actuation member **14***b* is formed so as to be movable in the vertical direction along the base needle bar **14***c*. Rotating force of the main spindle **22** is transmitted by the power transmission means, whereby the needle bar actuation member **14***b* is vertically actuated. The needle bar **12***b* is thereby moved in the vertical direction.

The presser foot is linked to the needle bar **12***b* and moves up and down in synchronism with vertical actuation of the needle bar **12***b*.

The main spindle motor **20** rotates the main spindle **22**, and rotating force of the main spindle **22** is transmitted by means of a predetermined power transmission mechanism, thereby actuating the respective machine elements, such as the thread take-up lever **12***a*, the needle bar **12***b*, and the presser foot, and the shuttle **12***c*. The main spindle motor **20** is constituted so as to rotate in one direction, whereby the main spindle **22** also rotates in one direction. The spindle angle represents the rotational position of the main spindle **22** and is synonymous with the rotational position of the main spindle motor **20** (i.e., the rotational position of an output shaft of the main spindle motor **20**).

The needle thread control section **30** is for drawing a needle thread from the thread roil **98** and controlling tension exerted on the needle thread. The needle thread control section **30** has an upstream grip section **40**, a downstream grip section **60**, and a turning section **80**.

Incidentally, the upstream grip section **40** has a grip section main body (an upstream grip section main body) **41** and a solenoid (an upstream actuation section) **50**. As a result of actuation of the solenoid **50**, the grip section main body **41** grips and fixes a needle thread. The grip section main body **41** is placed at a position on the front side of the case **110** that is beneath the pretension component **96** and above an opening section **110***a*. The solenoid **50** is put on a back side of the grip section main body **41** and in the case **110**.

The downstream grip section **60** has a grip section main body (a downstream grip section main body) **61** and a solenoid (a downstream actuation section) **70**. As a result of actuation of the solenoid **70**, the grip section main body **61** grips and fixes the needle thread. The grip section main body **61** is placed adjacently to the upstream grip section **40** along the horizontal direction; namely, on a part of the upstream grip section **40** closer to the thread take-up lever **12***a*. The solenoid **70** is placed on a back side of the grip section main body **61** and in the case **110**.

Since each of the upstream grip section **40** and the downstream grip section **60** has an analogous structure, an explanation is now given by means of taking the downstream grip section **60** as an example. The grip section main body **61** of the downstream grip section **60** has a tension disc group **62** and a supporting section **66**.

In the tension disc group **62**, a tension disc **62***a* and a tension disc **62***b* are placed opposite each other, so that the needle thread can be pinched between the pair of tension discs **62***a* and **62***b*. The pair of tension discs **62***a* and **62***b* has an approximately-circular-tabular (specifically a shape of a disc-shaped plate whose center protrudes outside) main body **63** and a tension disc frame **64** that upwardly extends at a slant from a circumferential edge of the main body **63**. The tension disc **62***a* and the tension disc **62***b* face each other in such a way that the tension disc frame **64** faces the outside.

Each of the supporting sections **66** supports the corresponding tension disc group **62** and has a plate-like section **66***a* and rods **66***b*. The plate-like section **66***a* assumes the shape of a square plate (a square shape each side of which is greater than a diameter of the tension discs **62***a* and **62***b*). The tension disc **62***a* is fixedly placed on a back side of the plate-like section **66***a*. Specifically, in the present embodiment, the tension disc **62***a* is attached so as to be nonrotatable. The rods **66***b* are fixedly provided at respective four corners of the plate-like section **66***a*. Ends of the respective rods **66***b* distant from the plate-like section **66***a* are secured to the front side of the case **110**.

The solenoid **70** is supported in the case **110**. The tension disc **62***b* is fixed to a leading end of a shaft portion **70***a* of the solenoid **70**. The shaft portion **70***a* of the solenoid **70** is moved to the front side by activation of the solenoid **70**, whereby the tension disc **62***b* is pushed toward the tension disc **62***a*. The needle thread J is gripped by means of the pair of tension discs **62***a* and **62***b*, whereupon the needle thread J is fixed. A state in which the solenoid **70** is activated is taken as a closed state of the grip section main body **61**. In the meantime, the needle thread J gripped between the pair of tension discs **62***a* and **62***b* is released by deactivating the solenoid **70**. As mentioned above, a state in which the solenoid **70** remains deactivated is taken as an open state of the grip section main body **61**.

In the downstream grip section **60**, the needle thread J drawn from the thread roll **98** remains pinched between the pair of tension discs **62***a* and **62***b*. In a state in which the solenoid **70** remains inactive, tension is not exerted on the needle thread pinched between the pair of tension discs **62***a* and **62***b*. Meanwhile, when the solenoid **70** is activated, the needle thread J becomes fixedly pinched between the tension disc **62***a* and the tension disc **62***b*. As above, the solenoid **70** working as a downstream actuation section is switched between a closed state in which the needle thread is gripped against the grip section main body **61** and an open state in which the needle thread is released. When the grip section main body **41** becomes closed, the gripped needle thread J is fixed. On the other hand, when the grip section main body **41** is opened, the needle thread J is released from the fixed state.

Since the upstream grip section **40** has a same structure as that of the downstream grip section **60**, its detailed explanation is omitted. The grip section main body **41** is structurally same to the grip main body **61**, and the solenoid **50** also has a structure same to that of the solenoid **70**. Specifically, when the solenoid **50** is activated, the needle thread J is gripped by means of the pair of tension discs, whereupon the grip section main body **41** is closed. On the contrary, when the solenoid **50** is released from the activated state, a grip effected by the pair of tension disc is canceled, whereupon the grip section main body **41** is opened. As above, the solenoid **50** acting as an upstream actuation section is switched between a closed state in which the needle thread is gripped against the grip section main body **41** and an open state in which the needle thread is released from the gripped state. When the grip section main body **61** is closed, the gripped needle thread J is fixed. By contrast, when the grip section main body **61** is opened, the needle thread J is released from the fixed state.

The solenoid is taken as an example device for switching each of the grip section main bodies **41** and **61** between the open state and the closed state. Another device (an actuator) that performs reciprocal movements can also be used.

The turning section **80** is placed at a downstream position with respect to the upstream grip section **40** in a direction of feed of a needle thread and an upstream position with respect to the downstream grip section **60** in the direction of feed of a needle thread. Specifically, the turning section **80** is placed below the upstream grip section **40** and the downstream grip section **60** and within the case **110**.

The turning section **80** has a turning arm **81** and a needle thread motor **86** that turns the turning arm **81**. The turning arm **81** has a rod-shaped main body section **82** and a tubular portion **84** provided at one leading end of the main body section **82**. An output shaft of the needle thread motor **86** is secured to the other end of the main body section **82**. The tubular portion **84** assumes a cylindrical shape (can also assume an approximately cylindrical shape) and is built in such a way that an axis line of the tubular portion **84** is parallel to a plane formed from a circle concentric to the output shaft of the motor and contacts the concentric circle. The turning section **80** is placed at such a position that the tubular portion **84** of the turning arm **81** is situated beneath the position between the grip section main body **41** and the grip section main body **61**. A position of the tubular portion **84** of the turning arm **81** (or approximately) coincides with an intermediate position between the pair of tension discs of the grip section main body **41** and the pair of tension discs of the grip section main body **61** with respect to a front-back direction of the tubular portion **84**. As mentioned above, the turning section **80** turns the needle thread situated between the grip section main body **41** and the grip section main body **61** [or may turn a part (or position) of a needle thread situated between the grip section main body **41** and the grip section main body **61**].

The control circuit **90** is a circuit for controlling operation of the main spindle motor **20**, the needle thread motor **86**, the solenoid **50**, and the solenoid **70** and controls operation of respective sections in accordance with the data stored in the memory device **92**. Specifically, the control circuit **90** generates main spindle data (see FIG. **7**) in accordance with the embroidery data read from the memory device **92**, controlling the main spindle motor **20** in accordance with the thus-generated main spindle data.

In accordance with the embroidery data read from the memory device **92**, the control circuit **90** generates needle thread control torque data (see FIG. **9**). In a torque control zone, the needle thread motor **86** is subjected to torque control in accordance with the needle thread control torque data. In a position control zone, the control circuit **90** generates angle correspondence data, such as that shown in FIG. **15**, and performs position control in accordance with the angle correspondence data.

In a zone ranging from an end point of the position control zone to an end point of the torque control zone, the control circuit **90** controls the solenoid **50** so as to close the upstream grip section **40**, controlling the solenoid **70** so as to open the downstream grip section **60**. In the meantime, in a zone ranging from the end point of the torque control zone to the endpoint of the position control zone, the control circuit **90** controls the solenoid **50** so as to open the upstream grip section **40**, controlling the solenoid **70** so as to close the downstream grip section **60**.

Specifically, as shown in FIG. **5**, the control circuit **90** has a CPU **90***a*, a PWM (Pulse Width Modulation) circuit **90***b*, and a current sensor **90***c*. In accordance with data from the memory device **92**, the CPU **90***a* outputs to the PWM circuit **90***b* data pertaining to a current value to be fed to the motor. The PWM circuit **90***b* converts an amplitude of the current value output from the CPU **90***a* into a pulse signal having a constant amplitude and feeds the pulse signal to the main spindle motor **20** and the needle thread motor **86**. The current sensor **90***c* converts a pulse signal output from the PWM circuit **90***b* into a current value, multiplies the current value by a constant to calculate a torque value, and outputs the torque value to the CPU **90***a*.

More specifically, in addition to generating needle thread control torque data in accordance with the embroidery data read from the memory device **92**, the control circuit **90** performs control as represented by flowcharts shown in FIG. **10** to FIG. **13**, FIG. **17**, FIG. **21**, and FIG. **22**, functional block, diagrams shown in FIG. **16** and FIG. **23**, and a timing chart shown in FIG. **18**. Detailed operations will be provided later. FIG. **18** shows example operation for one stitch performed in a control zone. A control zone for one stitch is one corresponding to one turn of the main spindle **22**.

An encoder **21** for detecting an angle of the main spindle motor **20** (the rotational position of the main spindle motor **20**) is interposed between the main spindle motor **20** and the control circuit **90**. An encoder **87** for detecting an angle of the needle thread motor **86** (a rotational position of the needle thread motor **86**) is interposed between the needle thread motor **86** and the control circuit **90**. The control circuit **90** detects angles of the respective motors (the rotational positions of the respective motors) from information output from the respective encoders.

The case **110** makes up an enclosure of the head **7** and is fastened to the frame **120**. The case **110** assumes an approximately square shape when viewed from the front and the back and an approximately-L-shaped geometry when viewed from the left. The case **110** assumes a shape such that a lower-side portion **110-1** protrudes to the front with respect to an upper-side portion **110-2**. The opening section **110***a* is formed in an upper end of an area of the lower-side portion **110-1** protruding from the upper-side portion **110-2**, and the needle thread J is inserted into the opening section **110***a*. A vertical slot **110***b* is formed on a left-side area on a front side of the upper-side portion **110-2** when viewed in plane. The thread take-up lever **12***a* is formed so as to protrude from the slot **110***b* to the front side (in direction Y**1**).

The main spindle motor **20**, the encoder **21**, and the main spindle **22** can also be disposed outside the case **110** that makes up the head **7**.

The shuttle **12***c* is placed at a position that is beneath the head **7** and lower than an upper surface of the sewing machine table. Specifically, the shuttle **12***c* is supported by a shuttle base (not shown) disposed below the sewing machine table.

The sewing frame **12***d* is a member for holding a processed fabric in a stretched manner and placed above (or on an upper surface of) the sewing machine table.

The frame actuator **24** is for actuating the sewing frame **12***d* in both an X-axis direction (direction X**1**-X**2**) and a Y-axis direction (direction Y**1**-Y**2**) in accordance with a command from the control circuit, and actuates the sewing frame **12***d* in synchronism with vertical movements of the needle bar **12***b*. Specifically, the frame actuator **24** is made up of a servomotor for actuating the sewing frame **12***d* in the X-axis direction, a servomotor for actuating the sewing frame **12***d* in the Y-axis direction, and others.

The memory device **92** stores embroidery data used for performing embroidery. The embroidery data here mean; for instance, data that pertain to a stitch width, a stitching direction, and thread attributes (a thread material and a thread thickness) and that are provided for each stitch.

As shown in FIG. **6**, the memory device **92** stores zone position data (zone data). In relation to the zone position data, data pertaining to the starting point and the end point of the torque control zone are stored as information about an angle of the main spindle (i.e., information about the rotational position of the main spindle motor **20**) (a starting point is denoted by reference symbol Z_1, and an end point is denoted by reference symbol Z_2). Moreover, data pertaining to the starting point and the endpoint of the position control zone are stored as information about an angle of the main spindle (i.e., information about the rotational position of the main spindle motor **20**) (a starting point is denoted by reference numeral Z_3, and an end point is denoted by reference symbol Z_4).

As shown in FIG. **18**, the starting point of the torque control zone is situated behind an end point of an immediately preceded position control zone in terms of time. Further, a starting point of a position control zone is situated behind an end point of an immediately preceding torque control zone in terms of time. Torque control and position control are switched after the opening and closing of the grip section main bodies **41** and **61** have been reliably switched. For this reason, a predetermined period of time exists between the end point of the torque control zone and the starting point of the position control zone. Further, a predetermined period of time exists between the end point of the position control zone and the starting point of the torque control zone. These predetermined periods of time are for switching the opening and closing of the grip section main bodies **41** and **61**.

The starting point of the torque control zone is at any arbitrary position in an area from the bottom dead center (one dead center) to the top dead center (the other dead center) within a turning range of the thread take-up lever (an area in which the thread take-up lever shifts from its bottom dead center to its top dead center) in association with rotation of the main spindle **22**. The top dead center of the thread take-up lever (the other dead center) can be said to be an end of the turning range of the thread take-up lever in the direction where the needle thread is pulled from the processed fabric.

The end point in the torque control zone is any arbitrary position in an area from the top dead center to any position on the way from the top dead center to the bottom dead center of the thread take-up lever and also a position achieved before the sewing needle **12***ba* is inserted into the processed fabric (e.g., a position where a leading end of the sewing needle **12***ba* comes to an elevated position above a steel plate **13**). In other words, in order to avoid as much as possible exertion of tension on the needle thread in the middle of sewing the processed fabric, a period during which the needle is being inserted into the processed fabric should not be taken as the torque control zone. Therefore, the end point of the torque control zone can also be the position of the top dead center of the thread take-up lever. Further, the top dead center of the shuttle is not taken as the torque control zone so that the shuttle can be smoothly inserted into the needle thread. Therefore, the end point of the torque control zone comes ahead of the top dead center of the shuttle.

In the torque control zone, tension is imparted to the needle thread J by means of pulling the needle thread J in a direction opposite to a direction of pull-up of the thread take-up lever **12***a* while the thread take-up lever **12***a* is pulling up the needle thread J. For these reasons, at least a portion of the torque control zone is set in a period during which the thread take-up lever is in the middle of ascending action (a period during which the needle thread is pulled with respect to the processed fabric). Specifically, the torque control zone can be said to be a zone including at least a portion of the area from the bottom dead center to the top dead center of the thread take-up lever. If torque control is performed even after the sewing needle **12***ba* has been inserted, tension will be exerted on the needle thread that is in the middle of sewing operation. For these reasons, the end point of the torque control zone is set to a position achieved before the sewing needle **12***ba* is inserted into the processed fabric.

The starting point of the position control zone is any arbitrary position in an area from the top dead center to the bottom dead center of the thread take-up lever (i.e., an area where a transition from the top dead center to the bottom dead center of the thread take-up lever takes place). It does not matter whether the starting point is a position achieved before the sewing needle **12***ba* is inserted into the processed fabric (i.e., a point at which the leading end of the sewing needle **12***ba* comes to an elevated position above the steel plate **13**) or a position achieved after the sewing needle **12***ba* is inserted into the processed fabric (e.g., a point at which the leading end of the sewing needle **12***ba* becomes lower than the steel plate **13**). In order to cause the shuttle to be inserted into the needle thread smoothly, the starting point of the position control zone is set ahead of the top dead center of the shuttle, and the top dead center of the shuttle is placed at any point in the position control zone.

The end point of the position control zone is at any position in the area from the bottom dead center to the top dead center of the thread take-up lever (i.e., the area where a transition from the bottom dead center to the top dead center of the thread take-up lever takes place). Since the endpoint is immediately followed by the torque control zone, the end point of the position control zone should preferably be at a position where the sewing needle **12***ba* has already gone out of the processed fabric (e.g., a position where the leading end of the sewing needle **12***ba* comes to an elevated position above the steel plate **13**).

The needle thread J is drawn from the thread roll **98** in the position control zone. However, in order to minimize the possibility of occurrence of a break in the needle thread by slowly drawing the needle thread while taking as long a time as possible, it is preferable to assure the longest possible position control zone. For instance, a long position control zone can be assured by means of setting the starting point of the position control zone at any arbitrary point ahead of the top dead center of the shuttle within the area from the top dead center to the bottom dead center of the thread take-up lever and setting the end point of the position control zone to any arbitrary point in the area from the bottom dead center to the top dead center of the thread take-up lever. Moreover, the area from the bottom dead center to the top dead center of the thread take-up lever corresponds to an area where the thread take-up lever pulls the needle thread against the processed fabric. Hence, it is preferable that the area be taken as the torque control zone. Consequently, it can preferably be said that the starting point of the torque control zone is taken as a period in the area from the bottom dead center to the top dead center of the thread take-up lever; namely, a period from the instant immediately following release of the sewing needle **12***ba* from an inserted state before the top dead center of the thread take-up lever (or the instant following arrival of the top dead center).

As above, the data pertaining to the starting point and the end point of the torque control zone and the starting point and the endpoint of the position control zone are specified as information about a main spindle angle. Although a term "zone" is employed, the main spindle motor **20** and the main spindle **22** rotate only in one direction. A control zone for one stitch becomes later in terms of time with an increase in main spindle angle. Therefore, a "period" can also be used in lieu of the "zone." For instance, a "torque control period" can also be adopted in place of the "torque control zone." Further, a "position control period" can also be adopted in place of the "position control zone." Moreover, a "control period" can also be used in place of the "control zone."

An explanation is now given to the needle thread J and its path. As shown in FIGS. **1** through **3**, the needle thread J drawn from the thread roll **98** is arranged so as to pass from an upstream side to a downstream side in sequence of the pretension component **96**, the grip section main body **41**, the tubular portion **84** of the turning arm **81**, the grip section main body **61**, the thread take-up lever **12***a*, and the sewing needle **12***ba*.

Operation of the sewing machine **5** having the above structure is now described by reference to FIG. **7** to FIG. **23**. First, operation of the needle thread motor **86** and operation of the solenoids **50** and **70** are described.

First, the control circuit **90** generates main spindle data (see FIG. **7**) for each stitch in accordance with the embroidery data stored in the memory device **92**. Since the memory device **92** stores, for each stitch, information about an embroidery to be generated, like a stitch width, a stitching direction, and thread attributes (a thread material and a thread thickness), main spindle data are generated according to the stitch width, the stitching direction, and the thread attributes for each stitch. As shown in FIG. **7**, the main spindle data are data pertaining to a main spindle angle (i.e., the rotational position of the main spindle motor **20**) achieved per unit time in a chronological order. For instance, when the stitch width is large, an amount of change in main spindle angle is decreased. On the contrary, when the stitch width is small, the amount of change in main spindle angle is increased. Moreover, when the stitching direction is opposite to the stitching direction employed last time, the amount of change in main spindle angle is decreased.

When the control circuit **90** generates the main spindle data, an entirety of embroidery data made up of a plurality of stitches can have been generated in advance. Alternatively, there can also be generated main spindle data pertaining to a stitch located several stitches ahead of a stitch by means of which the respective machine elements (the needle bar, the thread take-up lever, the shuttle, and the like) actually perform embroidering. Thereby, actual embroidering can also be performed while the main spindle data are being generated.

FIG. **8** shows example main spindle data. The main spindle data shown in FIG. **8** pertain to a case where the main spindle keeps rotating with constant velocity. When the respective stitches have a constant stitch width and when angles of the stitches are also oriented in the same direction, such main spindle data can be adopted. Incidentally, when a certain stitch has a large width, a time consumed to make one stitch is made longer. By contrast, when a certain stitch has a smaller stitch width, a time for one stitch is made shorter.

In accordance with the embroidery data stored in the memory device **92**, the control circuit **90** generates on a per-stitch basis needle thread control torque data used for controlling torque of the needle thread motor **86** (see FIG. **9**). Specifically, a torque value is determined for each stitch in connection with the needle thread control torque data. The torque value is determined in accordance with information provided for each stitch, like a stitch width, a stitching direction, a thread type, thread attributes, and the like. For instance, in the case of a large stitch width, fastening of the needle thread must be enhanced; therefore, the torque value is increased. When a thread has a large thickness, the fastening of the needle thread must be enhanced; therefore, the torque value is increased. As will be described later, the torque value is set to a value that does not pose any problem when the thread take-up lever **12***a* pulls the needle thread J in the torque control zone. On the occasion of generation of the needle thread control torque data, an entirety of embroidery data made up of a plurality of stitches can have been generated in advance. Alternatively, there can also be generated needle thread control torque data pertaining to a stitch located several stitches ahead of a stitch by means of which the respective machine elements (the needle bar, the thread take-up lever, the shuttle, and the like) actually perform embroidering. Thereby, actual embroidering can also be performed while the needle thread control torque data are being generated. Tension on the needle thread can be controlled for each stitch by means of the needle thread control torque data.

As shown in FIG. **10**, the main spindle angle is first detected during actual embroidering operation (S1). Specifically, a main spindle angle is detected from information from the encoder **21** connected to the main spindle motor **20**. The main spindle angle is detected at a predetermined cycle; for instance, a cycle of one-tenths to one-thousandths of a cycle for one stitch.

In accordance with a detected main spindle angle, it is determined that the main spindle motor is situated in which one of zones; namely, the torque control zone, the position control zone, and the other zone. In other words, as shown in FIG. **6**, the memory device **92** stores information about the starting point and the end point of the torque control zone and information about the starting point and the end point of the position control zone. Hence, a determination is made by comparing the detected main spindle angle with the information.

Specifically, a determination is made as to whether or not the main spindle angle is in the torque control zone (S**2**). When the main spindle angle is in the torque control zone, processing proceeds to a torque control subroutine (S**3**).

When the main spindle angle does not is in the torque control zone, a determination is made as to whether or not the main spindle angle is in the position control zone (S**4**). When the main spindle angle is in the position control zone, processing proceeds to position control subroutine (S**5**).

When the main spindle angle is not in the position control zone, the CPU **90***a* outputs a voltage value of 0 to the PWM circuit **90***b* (**36**), thereby halting a current supply to the needle thread motor **86** (S**7**). As mentioned above, a period during which the current supply to the needle thread motor **86** is halted corresponds to the area from the end point of the torque control zone to the starting point of the position control zone and the area from the end point of the position control zone to the starting point of the torque control zone which are shown in FIG. **18**. Specifically, a current supply halt time is set in order to switch between torque control and position control after the opening and closing of the grip section main bodies **41** and **61** have been reliably switched. Opening and closing of the grip section main bodies **41** and **61** effected during control operation, such as torque control operation and position control operation, can thereby be performed without fail.

When switching response of the grip section main bodies **41** and **61** can be made quick, it is also possible to bring the starting point of the torque control zone in agreement with the end point of the position control zone and also bring the starting point of the position control zone in agreement with the end point of the torque control zone.

Next, in the torque control subroutine, torque data (a torque value) pertaining to a target stitch are read from the needle thread control torque data at the starting point of the torque control zone. In the torque control zone for the stitch, torque is controlled in accordance with the thus-read torque data. Specifically, as shown in FIG. **11**, it is determined whether or not the torque data pertaining to the target stitch are stored in the control circuit **90** (S**11**). When the torque data are not yet retained at the starting point of the torque control zone, the torque data pertaining to the target stitch are read from the needle thread control torque data and retained in the control circuit **90** (S**12**).

When the torque data pertaining to the target stitch are retained, a torque value is read from the current sensor **90***c*, and the torque value thus detected by the current sensor **90***c* is subtracted from a value of the torque data pertaining to the target stitch (S**13** shown in FIG. **11**, and S**13** shown in FIG. **16**).

Next, the value calculated in step S**13** is multiplied by a predetermined constant, thereby calculating a voltage value (a voltage command to the PWM circuit) to be output to the PWM circuit **90***b* (S**14** shown in FIG. **11**, and S**14** shown in FIG. **16**). The thus-calculated voltage value is output to the PWM circuit **90***b* (S**15** shown in FIG. **11**, and S**15** shown in FIG. **16**).

In accordance with the thus-input signal, the PWM circuit **90***b* outputs a pulse signal as a voltage signal, thereby supplying an electric current to the needle thread motor **86** (S**16** shown in FIG. **11**, S**16** shown in FIG. **16**: a current supply step).

Control executed by the position control subroutine in the position control zone includes detecting an angle of the needle thread motor **86**; namely, a current rotational position of the needle thread motor **86** (i.e., a rotational position of an output shaft of the needle thread motor **86**); preparing angle correspondence data for controlling the rotational position of the needle thread motor **86** to its initial position (this may also expressed as "a position of origin"); and returning the needle thread motor **86** to its initial position in accordance with the angle correspondence data through position control. First, in relation to the target stitch, a determination is made as to whether or not the angle correspondence data are generated (S**21** shown in FIG. **12**).

When the angle correspondence data are not generated yet; namely, at the starting point of the position control zone, the angle of the needle thread motor **86** is detected by means of the encoder **87** (S**22** shown in FIG. **12**, and S**22** shown in FIG. **16**). In accordance with the thus-detected angle of the needle thread motor **86**, the angle correspondence data are generated (S**23** shown in FIGS. **12**, and **323** shown in FIG. **16**). As shown in FIG. **15**, the angle correspondence data are data pertaining to a correspondence between the main spindle angle (i.e., the rotational position of the main spindle motor **20**) and a needle thread motor angle (an angle of the needle thread motor) (the rotational position of the needle thread motor **86**). More specifically, the angle correspondence data are data pertaining to a correspondence between the main spindle angle and the needle thread motor angle from when the needle thread motor angle changes from C_n, achieved at the starting point of the position control zone (the main spindle achieved at the starting point of the position control zone is taken as a_x) to C_θ achieved at the end point of the position control zone (the main spindle angle achieved at the end point of the position control zone is taken as a_y). The main spindle angle and the needle thread motor angle represent rotational positions of the respective motors. The angle C_θ is an initial position angle of the needle thread motor **86**. On the occasion of generation of the angle correspondence data, a range from the main spindle angle a_x corresponding to the starting point of the position control zone to the main spindle angle a_y corresponding to the end point of the position control zone is divided into equal parts at predetermined intervals (unit angles) (namely, in units of one-n^{th} ("n" is an integer). As shown in FIG. **14**, in a first zone that is a predetermined area from the starting point of the position control zone (e.g., a main spindle angle a_x to a main spindle angle a_{x+3}), a gradual increase occurs in an amount of change in the needle thread motor per unit angle, whereby a turning speed of the turning arm **81** increases. In a second zone (e.g., the main spindle angle a_{x+3} to a main spindle angle a_{y-3}) following the first zone, the amount of change in needle thread motor angle per unit angle becomes constant. In a third zone (e.g., a main spindle angle a_{y-3} to a main spindle angle a_y) following the second zone, a gradual decrease occurs in the amount of change in needle thread motor angle per unit angle, whereby the turning speed of the turning arm **81** decreases. An angular range of the first zone and an angular range of the third zone are assumed to be shorter than an angular range of the second zone.

Data pertaining to the needle thread motor angle are read from the angle correspondence data (S**24** shown in FIG. **12** and S**24** shown in FIG. **16**). Specifically, a main spindle angle closest to the main spindle angle detected in step **S1** is detected from the angle correspondence data (FIG. **15**), and the needle thread motor angle corresponding to the main spindle angle is read. When data pertaining to two main spindle angles adjoining to the main spindle angle detected in step **S1** are found in the angle correspondence data, the needle thread motor angle can also be calculated according to a ratio of the detected main spindle angle to the two adjoining main spindle angles.

Speed data are now calculated by detecting an amount of change per unit time from the thus-read needle thread motor angle (S**25** shown in FIG. **12**, S**25** shown in FIG. **16**: a speed data calculation step). Speed data are calculated by dividing the amount of change in angle data by a time. Specifically, a relationship between the main spindle angle and the needle thread motor angle is specified by the angle correspondence data shown in FIG. **15**. Further, a relationship between a time and a main spindle angle is specified by the main spindle data shown in FIG. **7**. The amount of change in needle thread motor angle per unit time is thereby detected. When no match exists between main spindle angle data of the main spindle data and the main spindle angle data of the angle correspondence data, all you need to do; for instance, is to calculate a time from a ratio of the main spindle angle data of the main spindle data to a difference between two main spindle angles adjoining the main spindle angle of the angle correspondence data (the main spindle angle of the main spindle data).

Torque data are now calculated by detecting an amount of change in speed data per unit time (**526** shown in FIG. **12**, S**26** shown in FIG. **16**: a torque data calculation step). Specifically, torque data are calculated by dividing the amount of change in speed data by a time. In step S**25**, the speed data pertaining to the needle thread motor are calculated on a per-time basis; hence, torque data are calculated by differentiating the speed data.

Next, torque compensation data are calculated from the torque data calculated in step S**26** (S**27** shown in FIG. **12**, and S**27** shown in FIG. **16**). Specifically, the torque data are multiplied by an inertia ratio (S**27-1** shown in FIG. **16**), torque derived from a mechanical loss is added to a value determined by multiplying the torque data by the inertia ratio, thereby calculating torque compensation data (S**27-2** shown in FIG. **16**). The inertia ratio is a constant previously determined according to a mass of each of the machine elements, or the like. Further, the torque derived from a mechanical loss is a value previously determined in correspondence with each of the machine elements.

Data (a count value of the encoder) output from the encoder **87** (the encoder corresponding to the needle thread motor **86**) are subtracted from the angle data read in step S**24** (**528** shown in FIG. **13**, S**28** shown in FIG. **16**: a location deviation calculation step). A value calculated in step S**28** can be said to be a value of a location deviation.

The value calculated in step S**28** is now multiplied by a predetermined constant, thereby calculating a speed value (S**29** shown in FIG. **13** and S**29** shown in FIG. **16**).

A current motor speed value is calculated by differentiating the output from the encoder **87** (S**30** shown in FIG. **13** and S**30** shown in FIG. **16**). Specifically, an amount of change in encoder count value per unit time is calculated, thereby calculating a current motor speed value.

Next, the current motor speed value calculated in step S**31** is subtracted from the speed value calculated in step S**30**, and the speed data calculated in step S**25** are added to a subtraction result (S**31** shown in FIG. **13**, S**31** shown in FIG. **16**: a speed deviation calculation step). A value calculated in step S**31** can be said to be a value of speed deviation.

The value calculated in step S**31** is multiplied by a predetermined constant, thereby calculating a torque value (S**32** shown in FIGS. **13** and **532** shown in FIG. **16**).

Torque compensation data calculated in step S**27** are added to the torque value calculated in step S**32** (S**33** shown in FIG. **13**, and S**33** shown in FIG. **16**). Subsequently, the torque value output from the current sensor **90***c* is subtracted from the value calculated in step S**33** (S**34** shown in FIG. **13**, S**34** shown in FIG. **16**: a torque deviation calculation step). The value calculated in step S**34** can be said to be a torque deviation value.

The value calculated in step S**34** is multiplied by a predetermined constant, thereby calculating a voltage value (a voltage command to the PWM circuit) output to the PWM circuit **90***b* (S**35** shown in FIG. **13**, **335** shown in FIG. **16**). The voltage value is then output to the PWM circuit **90***b* (S**36** shown in FIG. **13**, and S**36** shown in FIG. **16**).

The PWM circuit **90***b* outputs a pulse signal as a voltage signal in accordance with an input signal, thereby supplying an electric current to the needle thread motor **86** (S**37** shown in FIG. **13**, S**37** shown in FIG. **16**: a current supply step).

As mentioned above, processing represented by flowcharts shown in FIGS. **10** to **13** is carried out at predetermined cycles, thereby controlling the needle thread motor **86**.

As shown in FIG. **18**, in relation to control of switching between the upstream grip section **40** and the downstream grip section **60**, the grip section main body **41** of the upstream grip section **40** is opened, and the grip section main body **61** of the downstream grip section **60** is closed from the end point of the torque control zone to the end point of the position control zone of the needle thread motor **86**. In the meantime, the grip section main body **41** of the upstream grip section **40** is closed, and the grip section main body **61** of the downstream grip section **60** is opened from the end point of the position control zone to the end point of the torque control zone.

Specifically, explanations are given along a flowchart shown in FIG. **17**. A main spindle angle is detected (S**41**) (detection of a main spindle angle is performed in the same manner as described in connection with the stitch S**1**). A determination is made as to whether or not the main spindle angle is situated at the end point of the torque control zone (S**42**). When the main spindle angle is at the end point of the torque control zone, the grip section main body **41** of the upstream grip section **40** is opened, and the grip section main body **61** of the downstream grip section **60** is closed. Specifically, the needle thread J is not fixed by the grip section main body **41** but fixed by the grip section main body **61**. Even when the main spindle angle has not reached the end point of the torque control zone yet on the occasion of detection of the previous main spindle angle (S**41**) and when the main spindle angle has passed on the endpoint of the torque control zone on the occasion of detection of the current main spindle angle (S**41**), the main spindle angle is determined to be at the end point of the torque control zone.

Further, when the main spindle angle is not at the end point of the torque control zone, a determination is made as to whether or not the main spindle angle is at the end point of the position control zone (S**44**). When the main spindle angle is at the endpoint of the position control zone, the grip section main body **41** of the upstream grip section **40** is closed, and the grip section main body **61** of the downstream grip section **60** is opened. Incidentally, even when the main spindle angle has not reached the end point of the position control zone yet on the occasion of detection of a previous main spindle angle (S**41**) and when the main spindle angle has passed on the end point of the position control zone on the occasion of detection of a current main spindle angle (S**41**), the main spindle angle is determined to be at the end point of the position control zone.

As mentioned above, in the torque control zone, the grip section main body **41** is closed, and the grip section main body **61** is opened. In the position control zone, the grip section main body **41** is opened, and the grip section main body **61** is closed.

Operation of the needle thread control section **30** is illustrated in a schematic manner as shown in FIG. **19**. When the main spindle angle is at the endpoint of the position control zone, the turning arm **81** is situated at the position of the bottom dead center (the initial position) (FIG. **19**(*a*)).

When the main spindle angle enters the torque control zone, the needle thread motor **86** is subjected to torque control while the grip section main body **41** is closed and while the grip section main body **61** is opened, whereby the needle thread motor **86** imparts downward rotating force to the turning arm **81**. Thereby, the thread take-up lever **12***a* turns upwardly while the turning arm **81** is pulling the needle thread J against a direction (a pulling direction) in which the thread take-up lever **12***a* pulls the needle thread J, thereby pulling the needle thread J with respect to the processed fabric. As the thread take-up lever **12***a* pulls the needle thread J, the turning arm **81** thereby turns in the direction (the upward direction) in which the thread take-up lever **12***a* pulls the needle thread J (FIGS. **19**(*b*), (*c*)).

Torque set in the needle thread control torque data is set to a value such that, as the thread take-up lever **12***a* pulls the needle thread J, the turning arm **81** turns in the direction (the upward direction) in which the thread take-up lever **12***a* pulls the needle thread J and does not hinder the thread take-up lever **12***a* from pulling the needle thread J (i.e., the thread take-up lever **12***a* can pull the needle thread J with respect to the processed fabric without impediment). Specifically, if the torque value is excessively large, the turning arm **81** will downwardly pull the needle thread J, thereby making the thread take-up lever **12***a* unable to turn upwardly to draw the needle thread J upwardly. For this reason, the torque value is set such that the thread take-up lever **12***a* is not hindered from pulling the needle thread J.

When the main spindle angle enters the position control zone, the needle thread motor **86** is subjected to position control while the grip section main body **41** is opened and while the grip section main body **61** is closed, whereupon the turning arm **81** turns in a direction (a downward direction) in which the needle thread J is pulled (FIG. **19**(*d*)). FIG. **19**(*d*) shows a state where the turning arm **81** turned to its initial position (this may also be expressed as "a position of origin") as a result of the needle thread motor **86** having returned to the initial position at the endpoint of the position control zone. FIG. **19**(*d*) is analogous to FIG. **19**(*a*).

When the torque value is large, the needle thread J is hardly pulled during torque control, so that a corresponding stitch is tightly sewn. On the contrary, when the torque value is small, the needle thread J is weakly pulled, so that a corresponding stitch is softly sewn.

Namely, in connection with FIG. **20**, FIG. **20**(*a*) shows a state achieved when the main spindle angle is at about 290 degrees in FIG. **18**; FIG. **20**(*b*) shows a state achieved when the main spindle angle is at about 330 degrees in FIG. **18**; FIG. **20**(*c*) shows a state achieved when the main spindle angle is at about 70 degrees in FIG. **18**; FIG. **20**(*d*) shows a state achieved when the main spindle angle is at about 110 degrees in FIG. **18**; and FIG. **20**(*e*) shows a state achieved when the main spindle angle is at about 170 degrees in FIG. **18**. The needle thread motor **86** is subjected to torque control in FIG. **20**(*b*) and FIG. **20**(*c*). When a torque value for a certain stitch is increased, the needle thread J is hardly pulled, so that the stitch is therefore tightly sewn. In the meantime, when the torque value is decreased, the needle thread J is weakly pulled, so that the stitch is softly sewn. In FIG. **20**, reference symbol K denotes a bobbin thread, and N denotes a processed fabric.

As above, in connection with a control zone for each stitch, in a torque control zone including at least a portion of an area from the bottom dead center to the top dead center of the thread take-up lever **12***a* that is a zone during which the thread take-up lever **12***a* pulls the needle thread with respect to the processed fabric to be sewn with the needle thread, there is performed torque control for imparting rotating force to the turning arm **81** in accordance with the torque value in such a way that tension is imparted to the needle thread against the direction in which the thread take-up lever **12***a* pulls the needle thread, while the grip section main body **41** is closed and while the grip section main body **61** is opened, in the meantime, in a position control zone which is at least one of the zones other than the torque control zone, there is performed position control for imparting rotating force to the turning arm **81** in accordance with angular position data pertaining to the needle thread motor **86** in such a way that the angle of the needle thread motor **86** returns to its initial angular position which is a rotational position of the needle thread motor **86**, while the grip section main body **41** is opened and while the grip section main body **61** is closed, thereby drawing the needle thread from upstream.

Control of the main spindle motor **20** is now described. Control of the main spindle motor **20** is performed in the same manner as in the case of position control of the needle thread motor **86**.

First, angle data (this can also be taken as position data) are read from the main spindle data (S**51** shown in FIG. **21**, S**51** shown in FIG. **23**: a reading step). Specifically, an angle (a main spindle angle) corresponding to a time that is an objective of processing is detected from the main spindle data, and data pertaining to the angle are read.

Next, there is detected an amount of change in the thus-detected main spindle angle per unit time, and speed data are calculated (S**52** shown in FIG. **21**, S**52** shown in FIG. **23**: a speed data calculation step). On the occasion of calculation of speed data, the amount of change in angle data is divided by a time, thereby calculating speed data. Namely, the speed data are calculated by differentiating the angle data.

The amount of change in speed data per unit time is detected, thereby calculating torque data (S**53** shown in FIG. **21**, S**53** shown in FIG. **23**: a torque data calculation step). On the occasion of calculation of torque data, the amount of change in speed data is divided by a time, thereby calculating torque data. Namely, torque data are calculated by differentiating the speed data. Speed data required to calculate the amount of change in speed are previously retained by the CPU **90***a*.

Torque compensation data are calculated from the torque data calculated in step S**53** (S**54** shown in FIG. **21**, S**54** shown in FIG. **23**). Specifically, torque data are multiplied by an inertia ratio (S**54-1** shown in FIG. **23**), and torque derived from a mechanical loss is added to a value determined by multiplying the torque data by the inertial ratio, thereby calculating the torque compensation data (S**54-2** shown in FIG. **23**). The inertia ratio is a constant previously determined according to a mass of each of the machine elements, or the like. Further, the torque derived from a mechanical loss is a value previously determined in correspondence with each of the machine elements.

Data (a count value of the encoder) output from the encoder **21** are subtracted from the angle data read in step S**51** (S**55** shown in FIG. **22**, S**55** shown in FIG. **23**: a location deviation calculation step). A value calculated in step 355 can be said to be a value of a location deviation.

The value calculated in step **S55** is now multiplied by a predetermined constant, thereby calculating a speed value (**S56** shown in FIG. **22** and **S56** shown in FIG. **23**).

A current motor speed value is calculated by differentiating the output from the encoder **21** (**S57** shown in FIG. **22** and **S57** shown in FIG. **23**). Specifically, an amount of change in encoder count value per unit time is calculated, thereby calculating a current motor speed value.

Next, the current motor speed value calculated in step **357** is subtracted from the speed value calculated in step **S56**, and the speed data calculated in step **S52** are added to a subtraction result (**558** shown in FIG. **22**, **S58** shown in FIG. **23**: a speed deviation calculation step). A value calculated in step **S58** can be said to be a value of speed deviation.

The value calculated in step **S58** is multiplied by a predetermined constant, thereby calculating a torque value (**559** shown in FIG. **22** and **S59** shown in FIG. **23**).

The torque value output from the current sensor **90***c* is subtracted from the torque value calculated in step **S59**. Further, torque compensation data calculated in step **S54** are added to a subtraction result (**S60** shown in FIG. **22**, and **S60** shown in FIG. **23**: a torque deviation calculation step). The value calculated in step **S60** can be said to be a torque deviation value.

The value calculated in step **S60** is multiplied by a predetermined constant, thereby calculating a voltage value (a voltage command to the PWM circuit) output to the PWM circuit **90***b* (**S61** shown in FIG. **22**, **S61** shown in FIG. **23**). The voltage value is then output to the PWM circuit **90***b* (**S62** shown in FIG. **22**, and **S62** shown in FIG. **23**).

The PWM circuit **90***b* outputs a pulse signal as a voltage signal in accordance with an input signal, thereby supplying an electric current to the main spindle motor **20** (**S63** shown in FIG. **22**, **S63** shown in FIG. **23**: a current supply step).

As mentioned above, the sewing machine of the first embodiment subjects the needle thread to torque control in the torque control zone, so that a magnitude of tension exerted on the needle thread can be controlled. In particular, torque control is performed on a per-stitch basis in the torque control zone by means of needle thread control torque data (FIG. **9**). Hence, tension exerted on the needle thread can be controlled on a per-stitch basis, so that seam hardness can be controlled on a per-stitch basis.

The needle thread control section **30** is provided in lieu of the tension disc, the rotary tension component, and the tension spring of the related-art sewing machine (see FIG. **46**). Thereby, the grip section main body **41** becomes open in the position control zone where the needle thread J is drawn. Only the pretension component **96** is present at an upstream position with respect to the turning arm **81** of the turning section **80**, and friction resistance does not exist between the tension disc and the rotary tension component. Moreover, since the grip section main body **61** becomes closed, movements of the thread take-up lever **12***a* will not pose any problems at the time of drawing of the needle thread. Consequently, the needle thread can be smoothly drawn from the thread roll, and the possibility of occurrence of a thread break can be reduced.

If a break has occurred in the needle thread, upward pulling of the turning arm **81**, which would otherwise occur when the thread take-up lever **12***a* moves to the top dead center, is prevented in the torque control zone. Specifically, the turning arm **81** will not be pulled in a direction opposite to the direction in which the rotating force of the needle thread motor **80** is imparted. Therefore, occurrence of a thread break can be detected by means of detecting that the turning arm **81** is not pulled upward. Further, when there is not a thread break, the turning arm **81** is pulled upward in the torque control zone, so that occurrence of a thread break can be detected accurately.

In the position control zone, a current position of the needle thread motor **86** is detected, and angle correspondence data for controlling the position of the needle thread motor **86** to its initial position are generated. Since there is performed control for returning the needle thread motor **86** to its initial position through position control in accordance with the angle correspondence data, the needle thread can be drawn, in the torque control zone, by only the amount corresponding to a quantity of thread consumed as a result of pulling of the turning arm **81**. Hence, an excess or deficiency of the quantity of accumulated thread, which would otherwise be caused by drawing a needle thread, will not arise.

Another example of the sewing machine **5** is now described by reference to FIG. **24**. In the example shown in FIG. **2** and FIG. **3**, the turning section **80** is disposed beneath the upstream grip section **40** and the downstream grip section **60**. However, in the example shown in FIG. **24**, the turning section **80** is disposed above the upstream grip section **40** and the downstream grip section **60**.

In the example shown in FIG. **2** and FIG. **3**, the thread take-up lever **12***a* is structured so as to turn upwardly, thereby drawing a needle thread J located downstream of the thread take-up lever **12***a*. In the example shown in FIG. **24**, the thread take-up lever **12***a* is constituted so as to draw the needle thread J located downstream of the thread take-up lever **12***a* by turning downwardly. Specifically, in the turning range of the thread take-up lever **12***a*, "the other dead center" that is the end in the direction in which the needle thread is drawn corresponds to a lower end. "The one dead center" corresponds to an upper end. An area from one dead center to the other dead center of the thread take-up lever **12***a* corresponds to a range where the needle thread is drawn with respect to the processed fabric.

Specifically, in the example shown in FIG. **24**, a cylindrical guide R**1** used for changing a direction of the path of the needle thread J is interposed between the thread roll **98** and the upstream grip section **40** along the path of the needle thread J. Likewise, a cylindrical guide R**2** used for changing the direction of the path of the needle thread J is interposed between the thread take-up lever **12***a* and the sewing needle **12***ba* along the path of the needle thread J.

In the turning section **80**, the needle thread motor **86** is subjected to torque control in the torque control zone, whereby rotating force is upwardly imparted to the turning arm **81**. The thread take-up lever **12***a* downwardly turns while the turning arm **81** is drawing the needle thread J against the direction in which the thread take-up lever **12***a* draws the needle thread J, thereby upwardly pulling the needle thread J with respect to the processed fabric. As the thread take-up lever **12***a* pulls the needle thread J, the turning arm **81** thereby turns in a direction (downward direction) in which the thread take-up lever **12***a* draws the needle thread J.

In the position control zone, the needle thread motor **86** is subjected to position control while the grip section main body **41** is opened and while the grip section main body **61** is closed, whereby the turning arm **81** turns in a direction (an upward direction) in which the needle thread J is drawn.

Although the above descriptions are provided on the assumption that the sewing machine **5** is an embroidery sewing machine, the sewing machine can also be another sewing machine other than the embroidery sewing machine. The needle thread control section **30** having the foregoing configuration and the control section for controlling the needle thread control section **30** are provided. In relation to a control zone for each stitch, in a torque control zone including at least a portion of an area from a bottom dead center to a top dead center of a thread take-up lever that is a zone in which the thread take-up lever draws the needle thread with respect to a processed fabric to be sewn with the needle thread, there is performed torque control for imparting rotating force to the turning arm **81** in accordance with a torque value so as to impart tension to the needle thread against a direction in which the thread take-up lever draws the needle thread while the grip section main body **41** is closed and while the grip section main body **61** is opened, in the meantime, in a position control zone which is at least one of the zones other than the torque control zone, there is performed position control for imparting rotating force to the turning arm **81** in accordance with angle position data pertaining to the needle thread motor **86** such that the angle of the needle thread motor **86** returns to its initial angular position that is a rotational position of the needle thread motor **86** while the grip section main body **41** is opened and while the grip section main body **61** is closed. Thus, the needle thread is drawn from upstream.

Second Embodiment

A sewing machine of a second embodiment is now described. A sewing machine **205** of the second embodiment is an embroidery sewing machine and structured as shown in FIGS. **25** to **28**. The sewing machine **205** has a head (an embroidering head) **207**, the shuttle **12***c*, the sewing frame **12***d*, the frame actuator **24**, and the memory device **92**. The sewing machine **205** is a multi-needle sewing machine; specifically, a six-needle embroidery sewing machine that can cope with six types of needle threads.

The head **207** is positioned above an approximately tabular sewing machine table (not shown) in the same way as is the head **7**. A frame **320** (see FIG. **27**) stands upright on an upper surface of the sewing machine table, and the head **207** is put on a front side of the frame **320**.

The head **207** is constituted as shown in FIGS. **25** to **28** and includes the machine element group **10**, the main spindle motor **20**, the main spindle **22**, a needle thread control section **230**, the control circuit **90**, needle thread guides **300** and **302**, and a case **310**.

The machine element group **10** is comprised of machine elements to be actuated in the head **207**. As with the first embodiment, the machine elements include thread take-up levers, needle bars, and presser feet (not shown). However, in the second embodiment, the head is equipped with a plurality of thread take-up levers and a plurality of needle bars; in other words, a plurality of (specifically six) thread take-up levers **12***a*-**1** to **12***a*-**6** and a plurality of (specifically six) needle bars **12***b*-**1** to **12***b*-**6**. The thread take-up levers **12***a*-**1** to **12***a*-**6**, the needle bars **12***b*-**1** to **12***b*-**6**, and the shuttle **12***c* are actuated by means of transmitting rotating force of the main spindle **22** by way of the power transmission means, like a cam mechanism or a belt mechanism, as in the case of the related-art sewing machine.

The thread take-up levers **12***a*-**1** to **12***a*-**6** are provided in a needle bar case **314** of the case **310** and are formed so as to be able to sway around an axis line (the rotating center) in the horizontal direction (the direction **X1**-**X2**) and perform turning action between the bottom dead center (one dead center) and the top dead center (the other dead center). The thread take-up levers **12***a*-**1** to **12***a*-**6** are axially supported by the needle bar case **314** so as to sway around the rotating center (that can also be referred to as a swaying center) **12***ab*. A needle thread to be inserted into the sewing needle **12***ba* is inserted into the thread take-up lever **12***a*. As a result of the needle bar case **314** sliding in the horizontal direction with respect to an arm **312**, power is transmitted solely to a specific selected thread take-up lever, whereupon the thread take-up lever is swayed. Leading ends of the respective thread take-up levers **12***a*-**1** to **12***a*-**6** project to the front (in direction **Y1**) from an opening section **316***d* formed in a front section **314***a* of the needle bar case **314**, to thus be exposed. Tension springs **292** [that can also be referred to as "thread take-up springs" (generally called "high tension springs")] (a second needle thread inverting member) for guiding the respective needle threads J sent from upward positions (i.e., from downstream grip sections **260**) are fixedly mounted at positions on the front section **314***a* of the needle bar case **314** that are low neighborhoods of the respective opening sections **316***d*. The tension springs **292** invert the needle threads J guided from upward positions and subsequently guide them to the respective thread take-up levers, and tension is exerted on the needle threads J. Like guide members **290**, rod-shaped guides can also be used in place of the tension springs **292**.

The needle bars **12***b*-**1** to **12***b*-**6** are provided in the needle bar case **314** so as to be movable in the vertical direction. The sewing needle **12***ba* (the needle thread is inserted into the pin hole **12***bb* of each of the sewing needles **12***ba*) is fixedly provided at a lower end of each of the needle bars **12***b*. The needle bar connecting stud **14***a* is fixedly provided at an upper end of each of the needle bars **12***b*. Further, the needle bar actuation member **14***b* is engaged with each of the needle bar connecting studs **14***a*. The vertically-oriented base needle bar **14***c* is inserted into each of the needle bar actuation members **14***b*. The needle bar actuation members **14***b* are formed so as to be movable in the vertical direction along the respective base needle bars **14***c*. Rotating force of the main spindle **22** is transmitted by the power transmission means, whereupon the needle bar actuation members **14***b* are vertically actuated. The needle bars are thereby moved in the vertical direction. The needle bar case **314** slides in the horizontal direction (the horizontal direction in FIG. **26**) with respect to the arm **312**, whereby the needle bar actuation member **14***b* is engaged with a specific needle bar connection stud **14***a*, so that a selected needle bar is vertically actuated. The presser foot is provided for each of the needle bars.

The main spindle **22** is rotated by the main spindle motor **20**, and the rotating force is transmitted by way of the predetermined power transmission mechanism, whereby the respective machine elements, like the thread take-up levers **12***a*-**1** to **12***a*-**6**, the needle bars **12***b*-**1** to **12***b*-**6**, and the presser foots, and the shuttles **12***c* are actuated. Incidentally, the main spindle motor **20** is configured so as to rotate in one direction.

The needle thread control section **230** is for drawing a needle thread from the thread roll wound around the needle thread bobbin (not shown) and controlling tension exerted on the needle threads. The needle thread control section **230** has an upstream grip section **240**, a downstream grip section **260**, a turning section **280**, and a needle thread supporting member **288**.

Incidentally, the upstream grip section **240** is mounted at an upstream position with respect to the head **207**; namely, an upstream position with respect to the turning section **280**. The upstream grip section **240** has a grip section main body (an upstream grip section main body) **241** and a magnet section (an upstream drive section and an upstream magnet section) **250** provided at a back side of the grip section main body **241**.

The grip section main body **241** has first plate-like sections (upstream first plate-like sections) **242**-**1** to **242**-**6** provided for the respective needle bars, a second plate-like section (an upstream second plate-like section) **244** that is provided on the back side of the first plate-like sections **242-1** to **242-6** and on the front side of the front section **314***a* of the needle bar case **314**; and mounting members **246** for mounting the first plate-like sections **242-1** to **242-6** and the second plate-like section **244** to the front section **314***a* of the needle bar case **314**.

Each of the first plate-like sections **242-1** to **242-6** assumes the shape of a rectangular plate and is formed from a material which is attracted by a magnet (a material to which a magnet adheres), or a magnetic substance (this can also be a ferromagnetic substance). Specifically, the first plate-like sections **242-1** to **242-6** are formed from metal attracted by a magnet; for instance, iron. All of the first plate-like sections are formed in (or approximately) a same size and a same shape. The first plate-like sections **242-1** to **242-6** are arranged side by side at intervals (specifically at uniform intervals) in the horizontal direction. Specifically, spacing exists between adjacent two first plate-like section units.

The second plate-like section **244** assumes the shape of an elongated rectangular plate. Specifically, the second plate-like section **244** is a single plate-like member disposed on the back side of the first plate-like sections **242-1** to **242-6**. The second plate-like section **244** horizontally has a width equal to a distance from a left lateral side of the first plate-like section **242-1** provided at the left end when viewed from the front to a right lateral side of the first plate-like section **242-6** provided at the right end when viewed from the front. In addition, the second plate-like section **244** has a vertical width (or approximately) equal to a vertical width of each of the first plate-like sections **242-1** to **242-6**. Specifically, the second plate-like section **244** is present on the back side of the respective first plate-like sections **242-1** to **242-6** and in parallel to the same. The second plate-like section **244** is formed from a material unattracted by the magnet (a material to which the magnet does not adhere); that is, a non-magnetic substance, and; for instance, aluminum and stainless steel.

A horizontally-elongated rectangular opening section (a second opening section) **316***a* is formed in an upper portion of the front section **314***a* of the needle bar case **314**. The second plate-like section **244** is provided so as to cover the opening section **316***a* from the front. Specifically, the opening section **316***a* is formed in a size that is smaller than the second plate-like section **244**. The vertical width of the second plate-like section **244** is larger than a leading end portion of the magnet section **250** and is formed so as to enable insertion of the leading end portion of the magnet section **250** into the opening section **316***a*.

The mounting members **246** are members for mounting the first plate-like sections **242-1** to **242-6** and the second plate-like section **244** to the needle bar case **314** and assume the shape of a pin. Each of the mounting members **246** is inserted into a first hole formed in a center (which can also be a substantial center) of an upper-side area of each of the first plate-like sections **242-1** to **242-6** and each of second holes formed in the second plate-like section **244** in correspondence to each of the first hole sections and fixed to the front section **314***a* of the needle bar case **314**. Thus, the first plate-like sections **242-1** to **242-6** and the second plate-like section **244** are attached to the front section **314***a* of the needle bar case **314**. Specifically, the mounting member **246** is provided for each of the first plate-like sections **242-1** to **242-6** and attached to the horizontal center (which can also be a substantial center) of an upper-side area of the first plate-like section in the horizontal direction. As above, the first plate-like sections **242-1** to **242-6** and the second plate-like section **244** are suspended by means of the respective mounting members **246** (or may hang from the mounting members). The first plate-like sections slide in the vertical direction with respect to a front surface of the second plate-like section **244**, whereby spacing between the first plate-like sections and the second plate-like section **244** varies (i.e., spacing between a surface of each of the first plate-like sections facing the second plate-like section **244** and a surface of the second plate-like section **244** facing the first plate-like sections varies).

The magnet section **250** is formed from an electromagnet, and a leading end of the magnet section is formed so as to be placed in an opening section **316***b* and contact the back side of the second plate-like section **244**. A surface (facing the second plate-like section **244**) of the leading end of the magnet section **250** works as an attracting surface. The magnet section **250** assumes a shape of an approximately quadrangular prism (the same also holds true for a magnet section **270**). The magnet sections **250** and **270** are structurally similar to an ordinary electromagnet and include a core made of a magnetic substance and a coil wound around the core. When energized, the magnet section generates magnetic force. One magnet section **250** is provided for the upstream grip section **240**. The control circuit **90** activates the magnet section **250**, whereupon any one of the first plate-like sections **242-1** to **242-6** corresponding to the position of the magnet section **250** is attracted by magnetic force. Spacing between the thus-attracted first plate-like section and the second plate-like section **244** is thus closed.

When the respective first plate-like sections are viewed from the front, rod-shaped guide members (first guide members) **252** are provided above the respective first plate-like sections **242-1** to **242-6**, and rod-shaped guide members (first guide members) **254** are provided below the respective first plate-like sections **242-1** to **242-6**. Namely, the guide members **252** and **254** are fastened to the front section **314***a* of the needle bar case **314**. The guide members **252** and **254** are arranged in such a way that the needle thread J diagonally passes on the back side of each of the first plate-like sections. Each of the guide members **252** is provided at an upper left point above each of the first plate-like sections when viewed from the front. Each of the guide members **254** is provided at a lower right point below each of the first plate-like sections when viewed from the front. A longer path can thereby be assured for the needle thread J that is on the back side of each of the first plate-like sections, so that the needle thread J can be caught between the first plate-like section and the second plate-like section **244** in a more reliable manner.

The downstream grip section **260** is placed at an approximately intermediate position on the head **207** along its vertical direction; namely, a position beneath the turning section **280**. The downstream grip section **260** has a grip section main body (a downstream grip section main body) **261** and the magnet section (a downstream actuation section or a downstream magnet section) **270** provided at the back side of the grip section main body **261**.

The grip section main body **261** has the same structure as that of the grip section main body **241**. Specifically, the grip section main body **261** has first plate-like sections (downstream first plate-like sections) **262-1** to **262-6** provided for the respective needle bars, a second plate-like section (a downstream second plate-like section) **264** that is provided on the back side of the first plate-like sections **262-1** to **262-6** and on the front side of the front section **314***a* of the needle bar case **314**; and mounting members **266** for mounting the first plate-like sections **262-1** to **262-6** and the second plate-like section **264** to the front section **314***a* of the needle bar case **314**.

The first plate-like sections **262-1** to **262-6** have a similar structure as that of the first plate-like sections **242-1** to **242-6**. Specifically, each of the first plate-like sections **262-1** to **262-6** assumes the shape of a rectangular plate and is formed from a material that is attracted by a magnet; namely, a magnetic substance (this can also be a ferromagnetic substance). The respective first plate-like sections are formed in (or approximately) a same size and a same shape. The first plate-like sections **262-1** to **262-6** are arranged side by side at intervals (specifically at uniform intervals) in the horizontal direction. Specifically, spacing exists between adjacent two first plate-like section units. Of the first plate-like sections **242-1** to **242-6** and the first plate-like sections **262-1** to **262-6**, the first plate-like sections assigned to the same needle thread are placed at the same position with reference to the horizontal direction.

The second plate-like section **264** has a similar structure as that of the second plate-like section **244**. Specifically, the second plate-like section **264** horizontally has a width equal to a distance from a left lateral side of the first plate-like section **262-1** provided at the left end when viewed from the front to a right lateral side of the first plate-like section **262-6** provided at the right end when viewed from the front. In addition, the second plate-like section **264** vertically has a width (approximately) equal to a vertical width of each of the first plate-like sections **262-1** to **262-6**. Specifically, the second plate-like section **264** is present on the back side of the respective first plate-like sections **262-1** to **262-6** and in parallel to the same. The second plate-like section **269** is formed from a material unattracted by the magnet; that is, a non-magnetic substance.

A horizontally-elongated rectangular opening section (a third opening section) **316***c* is formed in a substantial center of the front section **314***a* of the needle bar case **314** in its vertical direction. The second plate-like section **264** is provided so as to cover the opening section **316***c* from the front. Specifically, the opening section **316***c* is formed in a size that is smaller than the second plate-like section **264**. The vertical width of the second plate-like section **264** is larger than a leading end portion of the magnet section **270** and is formed so as to enable insertion of the leading end portion of the magnet section **270** into the opening section **316***c*.

The mounting members **266** are members for mounting the first plate-like sections **262-1** to **262-6** and the second plate-like section **264** to the needle bar case **314** and have the same structure as that of the mounting members **246**. The mounting members **266** are inserted into first holes that assume a pin shape and that are formed at centers (which can also be substantial centers) of upper-side areas of the respective first plate-like sections **262-1** to **262-6** and into second holes that are formed in the second plate-like section **264** and that correspond to the first hole sections, thereby being fixed to the front section **314***a* of the needle bar case **314**. The first plate-like sections **262-1** to **262-6** and the second plate-like section **264** are thereby attached to the front section **314***a* of the needle bar case **314**. Specifically, the mounting member **266** is provided for each of the first plate-like sections **262-1** to **262-6** and attached to the horizontal center (which can also be a substantial center) of the upper-side area of the first plate-like section along the horizontal direction. As above, the first plate-like sections **262-1** to **262-6** and the second plate-like section **264** are suspended by means of the respective mounting members **266** (or may hang from the mounting members). The first plate-like sections slide in the vertical direction with respect to a front surface of the second plate-like section **264**, whereby spacing between the first plate-like sections and the second plate-like section **264** varies (i.e., spacing between a surface of each of the first plate-like sections facing the second plate-like section **264** and a surface of the second plate-like section **264** facing the first plate-like sections varies).

The magnet section **270** is formed from an electromagnet in the same manner as is the magnet **250**, and a leading end of the magnet section is formed so as to be placed in the opening **316***c* and contact the back side of the second plate-like section **264**. A surface (facing the second plate-like section **264**) of the leading end of the magnet section **270** works as an attracting surface. One magnet section **270** is provided for the downstream grip section **260** and formed into (or approximately) the same size and the shape as those of the magnet section **250**. The control circuit **90** activates the magnet section **270**, whereupon any one of the first plate-like sections **262-1** to **262-6** corresponding to the position of the magnet section **270** is attracted by magnetic force. Spacing between the thus-attracted first plate-like section and the second plate-like section **264** is thus closed.

The magnet section **250** and the magnet section **270** are placed at the same position with reference to the horizontal direction. When the magnet section **250** and the magnet section **270** are activated, the magnet sections grip the same needle thread. For instance, in the example shown in FIG. **26**, the magnet section **250** is situated on the back side of the first plate-like section **242-4**, and the magnet section **270** is situated on the back side of the first plate-like section **262-4**. Therefore, the magnet sections **250** and **270** grip the same thread.

When the respective first plate-like sections are viewed from the front, rod-shaped guide members (second guide members) **272** are provided above the respective first plate-like sections **262-1** to **262-6**, and rod-shaped guide members (second guide members) **279** are provided below the respective first plate-like sections **262-1** to **262-6**. Namely, the guide members **272** and **274** are fastened to the front section **314***a* of the needle bar case **314**. The guide members **272** and **274** are arranged in such a way that the needle thread J diagonally passes on the back side of each of the first plate-like sections. Each of the guide members **272** is provided at an upper left point above each of the first plate-like sections when viewed from the front. Each of the guide members **274** is provided at a lower right point below each of the first plate-like sections when viewed from the front. A longer path can thereby be assured for the needle thread J that is on the back side of each of the first plate-like sections, so that the needle thread J can be caught between the first plate-like section and the second plate-like section **264** in a more reliable manner.

The turning section **280** is placed at an intermediate position between the upstream grip section **240** and the downstream grip section **260** along the vertical direction. More specifically, the turning section **280** is disposed at a downstream position in the direction in which the upstream grip section **240** feeds a needle thread and an upstream position in the direction in which the downstream grip section **260** feeds a needle thread. The turning section **280** is for turning the needle thread between the grip section main body **241** and the grip section main body **261** (or an area (a position) of the needle thread located between the grip section main body **241** and the grip section main body **261**).

The turning section **280** has a turning arm **281** and a needle thread motor **286** for rotating the turning arm **281**. As shown in FIG. **28**, the turning arm **281** has a rod-shaped main body section **282** and a hook section **284** provided at one leading end of the main body section **282**. An output shaft of the needle thread motor **286** is fastened to the other leading end of the main body section **282**. The hook section **284** assumes approximately a form of a U-shaped plate. When the turning arm **281** is turned, the hook section **284** can retain the needle thread J. Specifically, the hook section **284** has a groove section **284***a* provided in parallel to an axis line of the output shaft of the needle thread motor **286**. The hook section **284** is arranged so as to be able to contact and retain the needle thread J laid in parallel to the axis line of the output shaft of the needle thread motor **286** as a result of the turning arm **281** being upwardly turned around the output shaft (the rotating center) of the needle thread motor **286**. The turning arm **281** is interposed between the magnet section **250** and the magnet section **270** and can retain a selected needle thread.

The needle thread motor **286** is secured to the arm **312** and configured as follows. When the turning arm **281** is turned upward from a receded position (a position **281**(B) shown in FIG. **27**) that is obliquely downward on the front, the turning arm **281** projects to the front from the opening section (a first opening section) **316***b* formed between an opening section **316***a* and the opening section **316***c* with respect to the vertical direction of the front section **314***a* of the needle bar case **314**. Specifically, the opening section **316***b* is formed such that a leading end of the turning arm **281** can project to the front side (in direction Y**1**) of the needle bar case **314** (the front side is on the other side of the needle bar case **314** with respect to the arm **312**), to thus become exposed. When situated at the receded position, the turning arm **281** is configured so as not to contact the needle bar case **314** or a member (e.g., the needle thread supporting member **288**, or the like) provided in the needle bar case **314** even when the needle bar case **314** slides in its horizontal direction. The opening section **316***b* is provided in correspondence with each of the needle bars. The opening sections **316***b* are formed at positions between the first plate-like sections of the grip section main body **241** and the first plate-like sections of the grip section main body **261** corresponding to the respective first plate-like sections. The opening sections **316***b* assume a vertically-elongated rectangular shape. In the illustrated example, a total of six opening sections are provided. As mentioned above, the receded position is a position where the turning arm **281** will not contact the needle bar case **314** or any member provided on the needle bar case **314** even if the needle bar case **314** slides in its horizontal direction; at least, a position achieved as a result of the turning arm **281** having turned to a location that is lower than a position where the turning arm **281** contacts a needle thread supported by the needle thread supporting member **288** and also a position where the leading end of the turning arm **281** will not reach the opening section **316***b*.

The needle thread supporting member **288** for supporting the needle thread J in its horizontal direction is provided on either side of each of the opening sections **316***b* in the front section **314***a* of the needle bar case **314**. Specifically, the pair of needle thread supporting members **288** is provided in total on both sides of each of the opening sections **316***b*. The respective needle thread supporting members **288** have the same structure and are formed by folding back a wire into a circular-arc shape. Specifically, each of the needle thread supporting members **288** assumes a shape resulting from integration of: a circular-arc member **288***a* formed (approximately) concentrically with the rotating center of the needle thread motor **286**; a circular-arc member **288***b* formed approximately in parallel to the circular-arc member **288***a* on the other side of the circular-arc member **288***a* with respect to the axis line (the axis line passing through the rotating center) of the output shaft of the needle thread motor **286** and (or approximately) concentrically with the rotating center of the needle thread motor **286**; and a connecting member **288***c* that is formed in a circular-arc shape and that connects a lower end of the circular-arc member **288***a* to a lower end of the circular-arc member **288***b*. Specifically, the circular-arc member **288***a* and the circular-arc member **288***b* are formed concentrically with the rotating center of the needle thread motor **286** when viewed sideways. In one needle thread supporting member **288**, the circular-arc member **288***a* and the circular-arc member **288***b* are formed along a plane that forms a right angle with the axis line (the axis line passing through the rotating center) of the output shaft of the needle thread motor **286** while spaced apart from each other in a direction perpendicular to the axis line of the output shaft. The circular-arc member **288***a* and the circular-arc member **288***b* are formed at the same position with reference to the horizontal direction. Further, in relation to one needle thread supporting member **288**, the pair of needle thread supporting members **288** provided for one needle thread are spaced apart from each other in the horizontal direction. A portion of the circular-arc section **288***a* and a portion of the connecting member **288***c* are placed in the opening section **316***b*, and the circular-arc section **288***b* projects to the front from a front-side surface of the front section **314***a*. The needle thread is inserted into spacing between the respective circular-arc members **288***a* and the respective circular-arc members **288***b* of the pair of needle thread supporting members **288** from above, to thus be positioned between the pair of connecting members **288***c*. As a consequence, the needle thread J can be horizontally placed between the connecting members **288***c* of the pair of needle thread supporting members **288**. Even when the needle thread J is pull up by means of the turning arm **281**, the needle thread J comes to lie between the circular-arc member **288***a* and the circular-arc member **288***b*. Specifically, the needle thread supporting member **288** horizontally supports the needle thread at a position of the opening section **316***b* (namely, the position of the opening **316***b* in both the vertical and horizontal directions (more specifically, at a position of a lower side of the opening section **316***b*)). More specifically, the needle thread supporting member **288** horizontally supports the needle thread on the front side of the opening section **316***b* (or "at a position on the front side of the opening section **316***b*") when viewed from the front. Alternatively, the needle thread supporting member **288** can also horizontally support the needle thread in the opening section **316***b* (i.e., a position between the front surface and the back surface of the front section **314***a* in the front-back direction). As shown in FIG. **27**, lower ends of the needle thread supporting members **288** can also be configured so as to enter the needle bar case **314** from the opening **316***b*.

The rod-shaped guide member (a first needle thread path inverting member) **290** for guiding the needle thread J fed from above (in other words; from the upstream grip section **240**) to the needle thread supporting member **288** is secured to a position in the vicinity of a lower side of each of the openings **316***b* and on the front section **314***a* of the needle bar case **314**. The guide member **290** inverts the needle thread guided from above and subsequently guides the same to the needle thread supporting member **288**.

The control circuit **90** is a circuit for controlling operation of the main spindle motor **20**, operation of the needle thread motor **286**, operation of the magnet section **250**, and operation of the magnet section **270**. According to the data stored in the memory device **92**, the control circuit **90** controls operation of the individual sections. Specifically, the control circuit **90** generates main spindle data (see FIG. **7**) according to embroidery data read from the memory device **92** and controls operation of the main spindle motor **20** according to the thus-generated main spindle data.

According to the embroidery data read from the memory device **92**, the control circuit **90** generates needle thread control torque data (see FIG. **9**). In the torque control zone, the needle thread motor **286** is subjected to torque control in accordance with the needle thread control torque data. In a position control zone, the control circuit **90** generates angle correspondence data, such as that shown in FIG. **15**, and performs position control in accordance with the angle correspondence data.

In a zone ranging from the end point of the position control zone to the end point of the torque control zone, the control circuit **90** controls the magnet sections **250** and **270** so as to close the upstream grip section **240** and open the downstream grip section **260**. In the meantime, in a zone ranging from the end point of the torque control zone to the end point of the position control zone, the control circuit **90** controls the magnet sections **250** and **270** so as to open the upstream grip section **240** and close the downstream grip section **260**.

Specifically, as shown in FIG. **5**, the control circuit **90** has the CPU **90***a*, the PWM circuit **90***b*, and the current sensor **90***c* in the same manner as in the first embodiment. The respective sections; namely, the CPU **90***a*, the PWM circuit **90***b*, and the current sensor **90***c*, are structurally same to their counterparts described in connection with the first embodiment, and hence their repeated detailed descriptions are omitted. In the second embodiment, the solenoid **50** shown in FIG. **5** is replaced by the magnet section **250**, and the solenoid **70** is replaced by the magnet section **270**.

The encoder **21** for detecting an angle of the main spindle motor **20** (the rotational position of the main spindle motor **20**) is interposed between the main spindle motor **20** and the control circuit **90**. An encoder **287** for detecting an angle of the needle thread motor **286** (a rotational position of the needle thread motor **286**) is interposed between the needle thread motor **286** and the control circuit **90**. The control circuit **90** detects angles of the respective motors (the rotational positions of the respective motors) from information output from the respective encoders.

The case **310** makes up an enclosure of the sewing machine **205** (more specifically the head **207**). The case **310** has the arm **312** (which can also be taken as an arm section) secured to the frame **320** and the needle bar case **314** that is provided on the front side of the arm **312** and that slides in the horizontal direction with respect to the arm **312**. The arm **312** is equipped with the needle bar actuation member **14***b* and the base needle bar **14***c* for actuating the needle bars **12***b*-**1** to **12***b*-**6**, the magnet sections **250** and **270**, and the needle thread motor **286**. The arm **312** is formed approximately in a case form, thereby making up an enclosure of the sewing machine **205** (specifically the head **207**).

The needle bar case **314** is formed approximately into the shape of a case that can slide in the horizontal direction with respect to the arm **312**. The front section **314***a* has the opening section (the second opening section) **316***a* on which the magnet section **250** fronts, the plurality of opening sections (the first opening sections) **316***b* to which the respective turning arms **281** face and to each of which the pair of needle thread supporting members **288** are attached, the opening section (the third opening section) **316***c* on which the magnetic section **270** fronts, and the plurality of opening sections **316***d* through which the thread take-up levers **12***a*-**1** to **12***a*-**6** are exposed. The front section **314***a* is provided on the front side that is on the other side of the needle bar case **314** with respect to the arm **312**. The needle bar case **314** slides in the horizontal direction (the **X1**-**X2** direction) with respect to the arm **312** by means of an unillustrated sliding mechanism section.

The needle thread guides **300** are attached to an upper end region (a region that is higher than the guide members **252**) on the front-side surface of the needle bar case **314**, thereby guiding the respective needle threads in an insertable manner. In the illustrated example, the three needle thread guides **300** are provided. The needle thread guide **302** is also attached to a lower end region of the front-side surface of the needle bar case **314**, thereby guiding the respective needle threads in an insertable manner.

The main spindle motor **20**, the encoder **21**, and the main spindle **22** can also be disposed outside the case **310** that makes up the head **207**. For instance, in the case of a multi-head embroidery sewing machine equipped with a plurality of heads, a main spindle is provided in common to respective heads, and a main spindle motor for rotating the main spindle is provided.

The shuttle **12***c* is placed at a position that is beneath the head **207** and lower than the upper surface of the sewing machine table. Specifically, the shuttle **12***c* is supported by the shuttle base (not shown) disposed below the sewing machine table.

The sewing frame **12***d* is a member for holding the processed fabric in a stretched manner and placed above (or on an upper surface of) the sewing machine table.

The frame actuator **24** is for actuating the sewing frame **12***d* in both the X-axis direction (direction **X1**-**X2**) and the Y-axis direction (direction **Y1**-**Y2**) in accordance with a command from the control circuit, and actuates the sewing frame **12***d* in synchronism with vertical movements of the needle bar **12***b*. Specifically, the frame actuator **24** is made up of a servo motor for actuating the sewing frame **12***d* in the X-axis direction, a servo motor for actuating the sewing frame **12***d* in the Y-axis direction, and others.

The memory device **92** stores embroidery data used for performing embroidery. The embroidery data here mean; for instance, data that pertain to a stitch width, a stitching direction, a thread type (which one of a plurality of types of threads is used), and thread attributes (a thread material and a thread thickness) and that are provided for each stitch.

As shown in FIG. **6**, in the same manner as in the first embodiment, the memory device **92** stores data pertaining to the starting point and the end point of the torque control zone as information about a main spindle angle, and also data pertaining to the starting point and the endpoint of the position control zone as information about a main spindle angle. The starting point and the end point of the torque control zone and the starting point and the end point of the position control zone are same as those described in connection with the first embodiment, and hence their detailed explanations are omitted for brevity.

An explanation is now given to the path of the needle threads J. Six needle threads run along similar paths. Therefore, the needle thread situated at the right end when viewed from the front is taken as an example. The needle thread J guided from a thread roll (not shown) contacts the guide member **252** by way of the needle thread guide **300**; passes through spacing between the first plate-like section **242**-**6** and the second plate-like section **244** of the upstream grip section **240**, then contacts the guide member **254**, undergoes inversion on the guide member **290**, and subsequently reaches the needle thread supporting member **288**. The needle thread J passed through the pair of needle thread supporting members **288** contacts the guide member **272**, passes through spacing between the first plate-like section **262**-**6** and the second plate-like section **264** of the downstream grip section **260**, then contacts the guide member **274**, arrives at the thread take-up lever **12***a*-**6** by way of the tension spring **292**, and reaches a sewing needle of the needle bar **12***b*-**6** from the thread take-up lever **12***a*-**6** by way of the needle thread guide

302. The needle thread moves from the upstream side to the downstream side along the aforementioned sequence.

Operation of the sewing machine **205** having the above structure is now described. First, operation of the needle thread motor **286** and operation of the magnet sections **250** and **270** are described.

First, the control circuit **90** generates main spindle data (see FIG. **7**) for each stitch in accordance with the embroidery data stored in the memory device **92**. Since the memory device **92** stores, for each stitch, information about an embroidery to be generated, like a stitch width, a stitching direction, a thread type, and thread attributes (a thread material and a thread thickness), main spindle data are generated in accordance with the pieces of information about each stitch. As shown in FIG. **7**, the main spindle data are data pertaining to a main spindle angle achieved per unit time in a chronological order. For instance, when the stitch width is large, an amount of change in main spindle angle is decreased. On the contrary, when the stitch width is small, the amount of change in main spindle angle is increased. Moreover, when the stitching direction is opposite to the stitching direction employed last time, the amount of change in main spindle angle is decreased.

When the control circuit **90** generates the main spindle data, an entirety of embroidery data made up of a plurality of stitches can have been generated in advance. Alternatively, there can also be generated main spindle data pertaining to a stitch located several stitches ahead of a stitch by means of which the respective machine elements (the needle bar, the thread take-up lever, the shuttle, and the like) actually perform embroidering. Thereby, actual embroidering can also be performed while the main spindle data are being generated.

In accordance with the embroidery data stored in the memory device **92**, the control circuit **90** generates for each stitch needle thread control torque data used for controlling torque of the needle thread motor **286** (see FIG. **9**). Specifically, a torque value is determined for each stitch in connection with the needle thread control torque data. The torque value is determined in accordance with information provided for each stitch, like a stitch width, a stitching direction, a thread type, thread attributes, and the like. For instance, in the case of a large stitch width, fastening of the needle thread must be enhanced; therefore, the torque value is increased. When a thread has a large thickness, the fastening of the needle thread must be enhanced; therefore, the torque value is increased. On the occasion of generation of the needle thread control torque data, an entirety of embroidery data made up of a plurality of stitches can have been generated in advance. Alternatively, there can also be generated needle thread control torque data pertaining to a stitch located several stitches ahead of a stitch by means of which the respective machine elements (the needle bar, the thread take-up lever, the shuttle, and the like) actually perform embroidering. Thereby, actual embroidering can also be performed while the needle thread control torque data are being generated.

Operation performed during actual embroidering is analogous to that described in connection with the first embodiment. The sewing machine operates according to the flowcharts shown in FIG. **10** to FIG. **13** and FIG. **17**. However, in the second embodiment, a plurality of needle bars are provided, and a needle bar is selected from the plurality of needle bars (i.e., a thread is selected). Accordingly, a main spindle angle is detected along the flowchart shown in FIG. **10** (S**1**). When the detected main spindle angle is a main spindle angle corresponding to a start of one stitch (e.g., a zero degree in FIG. **18**) (in other words, when processing proceeds to the next stitch) and when a needle thread to be selected is subjected to a change, the following processing is performed between step S**1** and step S**2**. Namely, the needle bar case **314** is slid, to thus place the magnet sections **250** and **270** at the position of the selected thread. Further, sliding operation of the needle bar case **314** is controlled so that the turning arm **281** of the turning section **280** can retain and pull up the thus-selected thread.

When the needle bar case **314** is slid with respect to the arm **312**, the turning arm **281** is downwardly turned to the receded position designated by **281**(B) in FIG. **27**, to thus prevent the turning arm **281** from contacting the needle bar case **314** and a member provided on the needle bar case **314**.

Even in the torque control subroutine pertaining to step S**3** shown in FIG. **10**, operation is performed along the flowchart shown in FIG. **11** in the same way as in the first embodiment. Specifically, torque data (a torque value) pertaining to a target stitch are read from the needle thread control torque data at the starting point of the torque control zone. In the torque control zone for the stitch, torque is controlled in accordance with the thus-read torque data.

Even in the position control subroutine pertaining to step S**5** shown in FIG. **10**, operation is performed as illustrated by the flowcharts shown in FIGS. **12** and **13** and in the same manner as in the first embodiment. Specifically, the encoder **287** detects a current position (a rotational position) of the needle thread motor **286**. In the position control zone, angle correspondence data for controlling the position of the needle thread motor **286** to its initial position are generated (see FIG. **14** and FIG. **15**). The needle thread motor **286** is controlled so as to return its initial position in accordance with the angle correspondence data through position control.

Even in relation to control of switching between the upstream grip section **240** and the downstream grip section **260**, the grip section main body **241** of the upstream grip section **240** is opened, and the grip section main body **261** of the downstream grip section **260** is closed, as shown in FIGS. **17** and **18**, in a domain of the needle thread motor **286** from the end point of the torque control zone to the end point of the position control zone as in the case of the first embodiment. In the meantime, the grip section main body **241** of the upstream grip section **240** is closed, and the grip section main body **261** of the downstream grip section **260** is opened from the end point of the position control zone to the end point of the torque control zone. When the grip section main bodies **241** and **261** are closed, the gripped needle thread is fixed. On the contrary, when the grip section main bodies **241** and **261** are opened, the needle thread is released from the gripped state.

As a result of activation of the magnet section **250**, the first plate-like section corresponding to the position of the magnet section **250**, among the first plate-like sections **242-1** to **242-6**, is attracted by magnetic force. Spacing between the first plate-like section and the second plate-like section **244** is thereby closed, and the grip section main body **241** is also closed. Thus, there is achieved a closed state in which the needle thread J is pinched first plate-like section and the second plate-like section **244**. As shown in; for instance, FIG. **26**, when the magnet section **250** is situated on the back side of the first plate-like section **242-4**, the magnet section **250** is activated, whereby the spacing between the first plate-like section **242-4** and the second plate-like section **244** is closed. Thus, the needle thread is gripped between the first plate-like section **242-4** and the second plate-like section **244**. When the magnet section **250** is not activated, the spacing between the first plate-like section **242-4** and the second plate-like section **244** is not closed. Hence, the grip section main body **241** is opened, thereby achieving an open state in which the needle thread is released from the gripped state. As above, the magnet section **250** acting as the upstream drive section switches between the closed state in which the grip section main body **241** grips the needle thread and the open state in which the needle thread is released from the gripped state.

Likewise, as a result of activation of the magnet section **270**, the first plate-like section corresponding to the position of the magnet section **270**, among the first plate-like sections **262-1** to **262-6**, is attracted by magnetic force. Spacing between the first plate-like section and the second plate-like section **264** is thereby closed, and the grip section main body **261** is also closed. Thus, there is achieved a closed state in which the needle thread J is pinched between the first plate-like section and the second plate-like section **264**. As shown in; for instance, FIG. **26**, when the magnet section **270** is situated on the back side of the first plate-like section **262-4**, the magnet section **270** is activated, whereby the spacing between the first plate-like section **262-4** and the second plate-like section **264** is closed. Thus, the needle thread is gripped between the first plate-like section **262-4** and the second plate-like section **264**. When the magnet section **270** is not activated, the spacing between the first plate-like section **262-4** and the second plate-like section **264** is not closed. Hence, the grip section main body **261** is opened, thereby achieving an open state in which the needle thread is released from the gripped state. As above, the magnet section **270** acting as the downstream drive section switches between the closed state in which the grip section main body **261** grips the needle thread and the open state in which the needle thread is released from the gripped state.

Specifically, an explanation is given to operation of the needle thread control section **230**. At the end point of the position control zone, the turning arm **281** assumes a position of the top dead center (the initial position). Specifically, the hook section **284** of the turning arm **281** is situated at an obliquely upward position (a position designated by **281**(A) shown in FIG. **27**). The leading end of the turning arm **281** is exposed to the front side of the front section **314***a* from the opening section **316***b* at the initial position. When a change is made to the needle thread to be selected, the turning arm **281** is receded. Therefore, the turning arm **281** is turned to the receded position. On this occasion, the turning arm **281** is downwardly turned, thereby turning the needle thread to the receded position.

When the main spindle angle enters the torque control zone, the needle thread motor **286** is subjected to torque control while the grip section main body **241** is closed and the grip section main body **261** is opened, whereby the needle thread motor **286** imparts upward rotating force to the turning arm **281**. Thereby, the thread take-up lever **12***a***-1** turns upwardly while the turning arm **281** is pulling the needle thread J against a direction (a pulling direction) in which the thread take-up lever **12***a***-1**, or the like, pulls the needle thread J, thereby pulling the needle thread J with respect to the processed fabric. As the thread take-up lever **12***a***-1** pulls the needle thread J (i.e., the thread take-up lever **12***a* shifts to the top dead center (the other dead center)), the turning arm **281** turns in the direction (the downward direction) in which the thread take-up lever **12***a***-1**, or the like, pulls the needle thread J.

As in the case of the first embodiment, a torque value set in the needle thread control torque data is set to a value such that, as the thread take-up lever **12***a***-1**, or the like, pulls the needle thread J, the turning arm **281** turns in the direction (the downward direction) in which the thread take-up lever **12***a***-1**, or the like, pulls the needle thread J and does not hinder the thread take-up lever **12***a* from pulling the needle thread J.

When entered the position control zone, the needle thread motor **286** is subjected to position control while the grip section main body **241** is opened and while the grip section main body **261** is closed, whereupon the turning arm **281** turns in a direction (an upward direction) in which the needle thread J is pulled. Reference numeral **281**(A) shown in FIG. **27** shows a state where the turning arm **281** turned to its initial position as a result of the needle thread motor **286** having returned to the initial position (this can also be taken as a "position of origin") at the end point of the position control zone.

When the torque value is large, the needle thread J is hardly pulled during torque control, so that a stitch is tightly sewn. On the contrary, when the torque value is small, the needle thread J is weakly pulled, so that a corresponding stitch is softly sewn.

As above, in connection with a control zone for each stitch, in a torque control zone including at least a portion of an area from the bottom dead center to the top dead center of the thread take-up lever **12***a***-1**, or the like, that is a zone during which the thread take-up lever **12***a***-1**, or the like, pulls the needle thread with respect to the processed fabric to be sewn with the needle thread, there is performed torque control for imparting rotating force to the turning arm **281** in accordance with the torque value in such a way that tension is imparted to the needle thread against the direction in which the thread take-up lever **12***a***-1**, or the like, pulls the needle thread, while the grip section main body **241** is closed and while the grip section main body **261** is opened, in the meantime, in a position control zone which is at least one of the zones other than the torque control zone, there is performed position control for imparting rotating force to the turning arm **281** in accordance with angular position data pertaining to the needle thread motor **286** in such a way that the angle of the needle thread motor **286** returns to its initial angular position which is a rotational position of the needle thread motor **286**, while the grip section main body **241** is opened and while the grip section main body **261** is closed, thereby drawing the needle thread from upstream.

Control of the main spindle motor **20** is same to that described in connection with the first embodiment. Although the main spindle motor **20** operates along the flowcharts shown in FIGS. **21** and **22**, a plurality of needle bars are provided in the second embodiment, and a needle bar is selected from the plurality of needle bars (i.e., a thread is selected). On the occasion of a main spindle angle being read from the main spindle data in step S**51** of the flowchart shown in FIG. **21**, when the detected main spindle angle is a main spindle angle corresponding to the start of one stitch (e.g., zero degree in FIG. **18**) and when a needle thread to be selected is subjected to a change, there is performed the following process between steps S**51** and S**52**, namely, processing for sliding the needle bar case **314**, to thereby place the magnet sections **250** and **270** at the position of the thus-selected thread, and controlling sliding operation of the needle bar case **314** so as to come to the position of the opening section **316***b* corresponding to the thread so that the turning arm **281** of the turning section **280** can retain and pull up the thus-selected thread.

Control of the main spindle motor **20** is same to that described in connection with the first embodiment except that control of sliding operation of the needle bar case **314** is provided and, therefore, its detailed explanations are omitted.

As mentioned above in the sewing machine of the second embodiment, the needle thread is subjected to torque control in the torque control zone as mentioned above. Accordingly, the magnitude of tension on the needle thread can be controlled. In particular, torque control can be performed on a per-stitch basis in the torque control zone by means of the needle thread control torque data (FIG. **9**). Hence, tension on the needle thread can be controlled on a per-stitch basis, so that seam hardness can be controlled on a per-stitch basis.

In the case of the multi-needle head, even when a stitch is formed from a different needle thread, a torque value in the needle thread control torque data is made constant, whereby tension on the needle thread can be equally controlled. In the case of a multi-head embroidery sewing machine, the needle thread control torque data used for a torque control zone are made common to the heads, whereby tension on the needle threads exerted by the respective heads can be made equal.

Further, the needle thread control section **230** is provided in place of the tension disc and the rotary tension component in the related-art sewing machine (see FIG. **47**). In the position control zone where the needle thread J is drawn, the grip section main body **241** becomes open, and only the needle thread guide **300** is present at an upstream position with respect to the turning arm **281** of the turning section **280**. Frictional resistance does not exist between the tension disc and the rotary tension component. Further, the grip section main body **261** becomes closed. Hence, movements of the thread take-up lever **12***a* will not pose any problems at the time of drawing of the needle thread. Consequently, the needle thread can be smoothly drawn from the thread roll, thereby reducing the risk of occurrence of a thread break.

If a break has occurred in a needle thread, the turning arm **281** will not turn downwardly in the torque control zone. Specifically, the turning arm **281** will not be pulled in the downward direction opposite to the direction in which the rotating force of the needle thread motor **286** is imparted. A thread break can be detected by detecting that the turning arm **281** does not turn downwardly. Further, when there are not any thread breaks, the turning arm **281** downwardly turns in the torque control zone. Hence, occurrence of a thread break can be detected accurately.

In the position control zone, the current position (angle) of the needle thread motor **286** is detected. There are generated angle correspondence data for controlling the position of the needle thread motor **286** to its initial angle. There is performed control for returning the needle thread motor **286** to its initial position in accordance with the angle correspondence data through position control. The needle thread can therefore be drawn by only the amount corresponding to a quantity of thread consumed as a result of the turning arm **281** being pulled in the torque control zone. Hence, an excess or deficiency of the quantity of accumulated thread, which would otherwise be caused by drawing a needle thread, will not occur.

When the structure including the upstream grip section **240**, the downstream grip section **260**, and the turning section **280** is applied to the multi-needle head, the sewing machine can be configured by providing only one each of the magnet section **250** of the upstream grip section **240**, the magnet section **270** of the downstream grip section **260**, and the turning section **280**. Accordingly, the sewing machine can be provided with an efficient structure while its manufacturing cost is curtailed.

Third Embodiment

A sewing machine of a third embodiment is now described. A sewing machine **1205** of the third embodiment is an embroidery sewing machine and configured as shown in FIG. **29** to FIG. **36**. The sewing machine includes a head (an embroidering head) **1207**, the shuttle **12***c*, the sewing frame **12***d*, the main spindle motor **20**, the main spindle **22**, the frame actuator **24**, the control circuit **90**, and the memory device **92**. The sewing machine **1205** is a multi-needle sewing machine; specifically, a nine-needle embroidery sewing machine capable of coping with nine types of needle threads.

FIG. **33** and FIG. **34** are fragmentary left-side cross sectional views acquired when only a needle thread control mounting section **1340** and a needle thread control section **1230** are fractured at position P-P shown in FIG. **32**. FIG. **35** is a fragmentary left-side cross sectional view acquired when only the needle thread control mounting section **1340** and the needle thread control section **1230** are fractured at position Q-Q shown in FIG. **32**. FIG. **33**, FIG. **34**, and FIG. **35** show the sections while the needle thread is omitted.

Like the heads **7** and **207**, the head **1207** is disposed at an elevated position above an approximately-plate-like sewing machine table (not shown). Specifically, a frame (a frame having the same structure as that of the frame **320** (see FIG. **27**)) is disposed upright on the upper surface of the sewing machine table. The head **1207** is provided on the front side of the frame.

The head **1207** is structured as shown in FIG. **29** to FIG. **36** and has the machine element group **10**, the main spindle motor **20**, the main spindle **22**, the needle thread control section **1230**, the control circuit **90**, and a case **1310**.

The case **1310** makes up an enclosure of the sewing machine **1205** (specifically, the head **1207**). The case **1310** has an arm **1312** (this may also be taken as an "arm section") secured to the frame and a needle bar case **1314** that slides in a horizontal direction with respect to the arm **1312** provided on a front side (Y**1** side) of the arm **1312**.

The arm **1312** is formed approximately into a shape of a case extended in its front-back direction, making up an enclosure of the sewing machine **1205** (specifically the head **1207**). The arm **1312** has a shape enclosed by a square-shaped upper surface section **1312***a*; side surface sections **1312***b* and **1312***c* that continually extend from both lateral ends of the upper surface section **1312***a* in the downward direction and a front-side upper end of each of which has a square cutout; front surface section **1312***d* continually extending from front-side ends of the respective side surface sections **1312***b* and **1312***c* except their upper ends; front surface sections **1312***e* continually extending from the front-side ends in upper end areas of the respective side surface sections **1312***b* and **1312***c*; and upper surface section **1312***f* formed between lower ends of the respective front surface section **1312***e* and upper ends of the respective front surface section **1312***d*. A back-side end of the arm **1312** is connected to the frame.

A rail supporting section **1312***g* is provided on a front side of the arm **1312**, and a rail section **1334** provided on a back side of a needle bar case main body **1330** slidably fits on the rail supporting section **1312***g*.

A rail **1312***h* having a shape of an approximately inverted letter T is disposed on the upper surface section **1312***f*. The needle bar case main body **1330** is equipped with a sliding member **1314***h* that slides over the rail **1312***h*.

Power transmission means, such as a cam mechanism or a belt mechanism, for transmitting rotating force of the main spindle **22** to respective machine elements is provided in the arm **1312**.

A motor **1313***b* for letting the needle bar case **1314** slide and a clutch housing section **1313***a* are provided on an upper surface of the arm **1312**. The clutch housing section **1313***a* is provided with a clutch **1313***a*-**1** that is rotated by the motor **1313***b*. The clutch **1313***a*-**1** has a helical groove. The helical groove of the clutch **1313***a*-**1** is engaged with a cylindrical clutch engagement section **1339***b* provided on a back side of the needle bar case main body **1330**. As a result of the clutch **1313***a*-**1** being rotated, the needle bar case **1314** slides in the horizontal direction.

The needle bar case **1314** is formed approximately into a shape of a case that can slide in the horizontal direction with respect to the arm **1312**. The needle bar case **1314** has the needle bar case main body (a needle bar housing case) **1330** and the needle thread control mounting section **1340**.

The needle bar case main body **1330** is structured as shown in FIGS. **30**, **31**, **33**, **34**, and **35**. The needle bar case main body **1330** has an enclosure section **1332**; the rail section **1334** formed on a back side of the enclosure section **1332** along the horizontal direction; and supporting sections **1335**, guide members **1336**, tension springs (generally called "high tension springs") **1337**, and needle thread guides **1338** that are all provided on a front side of the enclosure section **1332**.

The enclosure section **1332** assumes a shape of a case that is formed in a vertically-elongated manner when viewed sideways. The enclosure section **1332** has a side surface section **1332***a* that is vertically long when viewed sideways and that has an upper end area protruding to the front and back sides; a side surface section **1332***b* formed symmetrical to the side section **1332***a*; a square-shaped front section **1332***c* interposed between a lower area of the side surface section **1332***a* and a lower area of the side surface section **1332***b*; an upper surface section **1332***d* that is interposed on the level between an upper end of the side surface section **1332***a* and an upper end of the side surface section **1332***b* in the horizontal direction; and a projecting section **1332***e* that is interposed between the front section **1332***c* and the upper surface section **1332***d* and that projects to the front rather than the front section **1332***c*. In relation to the projecting section **1332***e*, a plurality of projecting sections **1332***e* are spaced apart from each other. Opening sections (not shown) used for letting the thread take-up levers **12***a*-**1** to **12***a*-**9** project to the front are provided among the adjacent projecting sections **1332***e*.

The rail section **1334** is laid on the back side of the enclosure section **1332**; assumes a square-rod-shaped cross section; and is formed along the horizontal direction. The rail section **1334** is supported so as to be slidable in the horizontal direction by the rail supporting section **1312***g* secured to the arm **1312**. The rail supporting section **1312***g* and the rail section **1334** make up a linear way.

A plurality of cylindrical clutch engagement sections **1339***b* are provided along the horizontal direction, while spaced apart from each other, at an upper end on the back side of the enclosure section **1332** of the needle bar case main body **1330** by way of a horizontally-laid rod-shaped section **1339***a*. As a result of rotation of the motor **1313***b*, the clutch **1313***a*-**1** rotates, whereupon the needle bar case **1314** slides in the horizontal direction.

The supporting sections **1335** are mounted on the level (or approximately on the level) to an upper area of a front side of the front section **1332***c* of the enclosure section **1332** along the horizontal direction. The guide members **1336** are provided at intervals for respective thread take-up levers on the supporting sections **1335** and assume the shape of an approximately-L-shaped plate. The tension springs **1337** are provided at intervals for the respective thread take-up levers and attached to the supporting sections **1335** beneath the respective guide members **1336**. The tension springs **1337** are provided for guiding the needle threads J fed from above (namely, fed from the downstream grip section **1260**) to the respective thread take-up levers while preventing occurrence of a flexure or looseness of the needle thread J. The tension springs **1337** invert the respective needle threads J guided from above and subsequently lead the respective needle threads J to the respective thread take-up levers while exerting tension on the respective needle threads J. The needle thread guides **1338** are provided at a lower end on the front side of the front section **1332***c* along the horizontal direction.

The needle thread control mounting section **1340** is mounted on an upper surface of the needle bar case main body **1330** (particularly the enclosure section **1332**). The needle thread control mounting section **1340** has a plate-like plate section **1341**; plate section supporting sections **1344** that support the plate section **1341** in an upright position; guide members **1252**, **1254**, **1272**, **1274**, and **1290** attached to the plate section **1341**; and needle thread guides **1300** and **1302**, guide plates **1346***a* and **1346***b*, rest sections **1347***a* and **1347***b*, and presser plates **1348***a* and **1348***b*.

The plate section **1341** assumes a shape of a (or approximately) rectangular plate. Formed in the plate section **1341** are an opening section (a second opening section) **1342***a* on which a magnet section **1250** fronts, a plurality of (nine in the illustrated example) opening sections (first opening sections) **1342***b* on which a turning arm **1281** fronts and that each are used for mounting a pair of needle thread supporting members **1288**; and an opening section (a third opening section) **1342***c* on which a magnet section **1270** fronts. The plate section **1341** is formed in the horizontal direction, and upper and lower sides of the plate section **1341** are oriented along the horizontal direction.

The opening section **1342***a* is formed into a horizontally elongated rectangular shape above the opening sections **1342***b*. A vertical width of the opening section **1342***a* is larger than a leading end portion of the magnet section **1250**, to thus make it possible to insert the leading end portion of the magnet section **1250** into the opening section **1342***a*. Likewise, the opening section **1342***c* is formed into a horizontally elongated rectangular shape below the opening sections **1342***b*. A vertical width of the opening section **1342***c* is larger than a leading end portion of the magnet section **1270**, to thus make it possible to insert the leading end portion of the magnet section **1270** into the opening section **1342***c*.

The opening sections **1342***b* are provided in correspondence with the respective needle bars. The opening sections **1342***b* are formed at a position between a first plate-like section unit in a grip section main body **1241** and a first plate-like section unit in a grip section main body **1261** corresponding to the counterpart first plate-like section unit (i.e., a position between the a first plate-like section **1242***a* and a first plate-like section **1262***a* corresponding to the first plate-like section **1242***a*). Specifically, the opening sections **1342***b* assume a vertically-long rectangular shape. In the illustrated example, a total number of nine opening sections **1342***b* are provided. The opening sections **1342***b* are placed along the horizontal direction at spacing (specifically regular intervals). The opening sections **1342***b* are formed so that a leading end of the turning arm **1281** can project to the front side (Y**1** side) of the plate section **1341** (the front side is on the other side of the plate section **1341** with respect to the arm **1312**) in an exposed manner.

The plate section supporting section **1344** is provided at each of horizontal ends on the back side of the plate section **1341**, assuming an approximately-C-shaped frame. Each of the plate section supporting sections **1344** is attached to an upper surface of the enclosure section **1332**. The plate section **1341** is attached to the front side of the enclosure section **1332** and supported by the enclosure section **1332**. The plate section **1341** is attached in such a way that a front-side surface of the plate section **1341** faces in an oblique upward direction.

The guide members **1252**, **1254**, **1272**, **1274**, and **1290** are provided vertically to a front-side surface of the plate section

1341 upright on the front-side surface of the plate section 1341. The guide member 1252 and the guide member 1254 are provided for each of first plate-like section units 1242-1 to 1242-9. The guide members 1252 are disposed at intervals along an upper side of the opening section 1342*a*. The guide members 1254 are disposed at intervals along a lower side of the opening section 1342*a*. The guide members 1272, the guide members 1274, and the guide members 1290 are provided for each of first plate-like section units 1262-1 to 1262-9. The guide members 1272 are disposed at intervals along an upper side of the opening section 1342*c*. The guide members 1274 are disposed at intervals along a lower side of the opening section 1342*c*. The guide members (the first needle thread path inverting members) 1290 are disposed at intervals along an upper side surface of the opening section 1342*c* while spaced apart from the respective guide members 1272.

FIG. 46 shows a conceivable method for attaching the guide members 1252, 1254, 1272, 1274, and 1290 and the guide members 252, 254, 272, 274, and 290.

Specifically, all the guide members 1252, 1254, 1272, 1274, and 1290 assume a similar configuration. Hence, an explanation is now provided by means of taking the guide member 1252 as an example. Each of the guide members 1252 has an approximately cylindrical main body section ga-1 and a screw section (a base end section) ga-2 projecting from a base end of the main body section ga-1. A thread groove is formed in an outer periphery of the screw section ga-2.

Specifically, the main body section ga-1 has a cylindrical outer peripheral surface and a hemispherical leading end. The screw section ga-2 assumes an approximately cylindrical shape, and a thread groove is formed in the cylindrical peripheral surface. A radius (diameter) of the screw section ga-2 is smaller than a radius (diameter) of the main body section ga-2.

In an example shown in FIG. 46(*a*), screw holes 1343*a* to be screw-engaged with the respective screw sections ga-2 are formed in the plate section 1341. The screw sections ga-2 are attached to the respective screw holes 1343*a*, whereby base end faces of the respective main body sections ga-1 contact the surface of the plate section 1341.

In the example shown in FIG. 46(*b*), indentations 1343*b* used for inserting the base end sections (i.e., ends facing the screw sections ga-2) of the respective main body sections ga-1 and the screw holes (hole sections) 1343*a* continually extending from the respective indentations 1343*b* are formed in the plate section 1341. Hole sections that completely pass through the plate section 1341 from the front side to the back side of the plate section 1341 are formed from the respective indentations 1343*b* and the respective screw holes 1343*a*. The screw sections ga-2 are attached to the respective screw holes 1343*a*, whereby the base end sections of the respective main body sections ga-1 are inserted into the respective indentations 1343*b*. Specifically, the base end sections of the main body section ga-1 are embedded in the plate section 1341. Although the screw holes 1343*a* pass through to the back side of the plate section 1341, the screw holes can also be formed into indented hole sections that do not completely pass through to the back side of the plate section 1341.

The configuration shown in FIG. 46(*b*) makes it possible to prevent a chance of the needle thread entering spacing between the base end of each of the main body sections ga-1 and the surface of the plate section 1341. Specifically, in the configuration 46(*a*), the base end face of each of the main body sections ga-1 contacts a front-side face of the plate section 1341. Hence, there is a risk of the needle thread entering spacing between the base end face of each of the main body sections ga-1 and a front-side surface of the plate section 1341 and being caught by the spacing. However, the method shown in FIG. 46(*b*) makes it possible to avoid the risk.

Although a method illustrated in FIG. 46(*c*) is approximately identical with the method illustrated in FIG. 46(*b*) the method shown in FIG. 46(*c*) is directed toward an example in which the screw section ga-2 projects from the screw hole 1343*b* and in which a nut ga-3 is attached to the screw section ga-2. Even in the case of the method illustrated in FIG. 46(*c*), the base end portion of the main body section ga-1 is inserted and embedded in the indentation 1343*b*. Hence, a risk of the needle thread entering spacing between the base end of each of the main body sections ga-1 and the surface of the plate section 1341 can be avoided.

The needle thread guides 1300 are disposed in an upper region on the front side of the plate section 1341 (a region above the guide members 1252), thereby guiding the respective needle threads in an insertable manner. In the illustrated example, the five needle thread guides 1300 are provided.

The needle thread guides 1302 are disposed in a lower region on the front side of the plate section 1341 (a region beneath the guide members 1274), thereby guiding the respective needle threads in an insertable manner. In the illustrated example, the five needle thread guides 1302 are provided.

The guide plate 1346*a* assumes the shape of an elongated rectangular plate and disposed in the horizontal direction on the back side of the plate section 1341 and along an upper side on a back surface of the opening section 1342*a*. The guide plate 1346*a* is placed on the back side of a retaining section 1242*b* for the first plate-like section units 1242-1 to 1242-9, preventing droppage of the first plate-like section units 1242-1 to 1242-9 from the plate section 1341. The rest section 1347*a* is provided at each of right and left lateral ends of the back side of the plate section 1341 while interposed between the guide plate 1346*a* and the back side of the plate section 1341, thereby forming spacing between the guide plate 1346*a* and the plate section 1341. Thus, the rest section 1347*a* makes it possible for the first plate-like section units 1242-1 to 1242-9 to make sliding actions in the front-back direction with no difficulty.

The guide plate 1346*b* assumes the shape of an elongated rectangular plate and disposed in the horizontal direction on the back side of the plate section 1341 and along an upper side on a back surface of the opening section 1342*c*. The guide plate 1346*b* is placed on the back side of a retaining section 1262*b* for the first plate-like section units 1262-1 to 1262-9, preventing droppage of the first plate-like section units 1262-1 to 1262-9 from the plate section 1341. The rest section 1347*b* is provided at each of right and left lateral ends of the back side of the plate section 1341 while interposed between the guide plate 1346*b* and the back side of the plate section 1341, thereby forming spacing between the guide plate 1346*b* and the plate section 1341. Thus, the rest section 1347*b* makes it possible for the first plate-like section units 1262-1 to 1262-9 to make sliding actions in the front-back direction with no difficulty.

The presser plates 1348*a* are provided on both sides of the opening section 1342*a* on the front surface of the plate section 1341. Right and left lateral side ends of a second plate-like section 1244 are sandwiched between the presser plates 1348*a* and the plate section 1341. The presser plates 1348*b* are provided on both sides of the opening section 1342*c* on the front surface of the plate section 1341. Right and left lateral side ends of a second plate-like section 1264 are sandwiched between the presser plates 1348*b* and the plate section 1341.

The machine element group **10** is comprised of machine elements to be actuated in the head **1207**. As with the first and second embodiments, the machine elements include the plurality of thread take-up levers, the plurality of needle bars, and the presser feet. However, in the third embodiment, the head is equipped with nine thread take-up levers **12***a*-**1** to **12***a*-**9**, nine needle bars **12***b*-**1** to **12***b*-**9**, and nine presser feet **12***e*. The thread take-up levers **12***a*-**1** to **12***a*-**9**, the needle bars **12***b*-**1** to **12***b*-**9**, and the shuttle **12***c* are actuated by means of transmitting rotating force of the main spindle **22** by way of the power transmission means, like a cam mechanism or a belt mechanism, as in the case of the related-art sewing machine. Incidentally, the number of thread take-up levers, needle bars, and presser feet can also be any number other than nine (e.g., 12).

The thread take-up levers **12***a*-**1** to **12***a*-**9** are provided in the enclosure section **1332** of the needle bar case main body **1330** of the case **1310** and are formed so as to be able to sway around an axis line (the rotating center) in the horizontal direction (the direction **X1**-X2) and turn between the bottom dead center (one dead center) and the top dead center (the other dead center). Specifically, the thread take-up levers **12***a*-**1** to **12***a*-**9** are axially supported by the needle bar case main body **1330** so as to sway around the rotating center (this can also be taken as a "swaying center") **12***ab*. Needle threads to be inserted into the respective sewing needles are inserted into the respective thread take-up levers **12***a*-**1** to **12***a*-**9**. Power is transmitted to only a selected, specific thread take-up lever as a result of the needle bar case **1314** sliding in the horizontal direction with respect to the arm **1312**, whereupon the specific thread take-up lever is swayed. In other words, base ends **12***az* (see FIG. **31**) of the respective thread take-up levers **12***a*-**1** to **12***a*-**9** are engaged with engagement members **1313***z* of the arm **1312**. The thread take-up levers are then swayed as a result of the engagement members **1313***z* turning around a turning center. Leading ends of the respective thread take-up levers **12***a*-**1** to **12***a*-**9** project to the front (in direction **Y1**), in an exposed manner, from the respective opening sections provided between the adjacent projecting sections **1332***e* on the front side of the enclosure section **1332**.

The needle bars **12***b*-**1** to **12***b*-**9** are provided in the enclosure section **1332** so as to be movable in the vertical direction. Sewing needles (sewing needles having the same structure as those of the sewing needles **12***ba* described in connection with the second embodiment, and needle threads are inserted into pin holes of the respective sewing needles) are fixedly provided at lower ends of the respective needle bars. The needle bar connecting stud **14***a* is fixedly provided at the upper end of each of the needle bars **12***b*. Further, a needle bar actuation member (a needle bar actuation member having the same structure as that of the needle bar actuation member **14***b* described in connection with the second embodiment) is engaged with each of the needle bar connecting studs **14***a*. Abase needle bar (a base needle bar having the same structure as that of the base needle bar **14***c* described in connection with the second embodiment) provided in the vertical direction is inserted into each of the needle bar actuation members. The needle bar actuation members are formed so as to be movable in the vertical direction along the respective base needle bars. Rotating force of the main spindle **22** is transmitted by the power transmission means, whereupon the needle bar actuation members are vertically actuated. The needle bars are thereby moved in the vertical direction. The needle bar case **314** slides in the horizontal direction with respect to the arm **1312**, whereby the needle bar actuation member is engaged with a specific needle bar connection stud **14***a*, so that a selected needle bar is vertically actuated. The presser foot **12***e* is provided for each of the needle bars.

The needle thread control section **1230** is for drawing a needle thread from the thread roll (not shown) wound around the needle thread bobbin and controlling tension exerted on the needle threads. The needle thread control section **1230** has an upstream grip section **1240**, the downstream grip section **1260**, a turning section **1280** (see FIG. **29**, FIG. **34**, and FIG. **35**), and a supporting section (a magnet section and a motor supporting member) **1360**.

Incidentally, the upstream grip section **1240** is placed at an upper area of the plate section **1341**; namely, an area above the turning sections **1280**. The upstream grip section **1240** has the grip section main body (an upstream grip section main body) **1241** and the magnet section (an upstream drive section and an upstream magnet section) **1250** provided on a back side of the grip section main body **1241**.

The grip section main body **1241** has the first plate-like section units **1242-1** to **1242-9** provided for the respective needle bars and the second plate-like section (an upstream second plate-like section) **1244** that is provided on the back side of the first plate-like section **1242***a* in the first plate-like section units **1242-1** to **1242-9** and on the front side of the needle bar case **1314** (specifically the plate section **1341**).

As shown in FIG. **36**, each of the first plate-like section units **1242-1** to **1242-9** includes the first plate-like section (an upstream first plate-like section) **1242***a* assuming the shape of a square-shaped plate and the retaining section (a mounting member) **1242***b* formed so as to project from an upper end of the first plate-like section **1242***a* to the back. The retaining section **1242***b* assumes the shape of an approximately-L-shaped plate (a shape made by bending a rectangular plate approximately into the letter L). The first plate-like section unit is integrally formed from a material which is attracted by a magnet (a material to which a magnet adheres); that is, a magnetic substance (or a ferromagnetic substance instead). Specifically, each of the first plate-like section units **1242-1** to **1242-9** is formed from metal attracted by a magnet, like iron. The first plate-like section units are formed in (or approximately) a same size and a same shape. As a result of the retaining sections **1242***b* being engaged with retaining holes **1342***d* formed in the plate section **1341**, the first plate-like section units **1242-1** to **1242-9** are arranged at spacing (specifically uniform intervals) side by side along the horizontal direction. Spacing exists between two adjacent first plate-like section units. The plurality of (specifically, a total of nine) retaining holes **1342***d* are arranged at spacings (specifically uniform intervals) side by side along the horizontal direction and at an area on the plate section **1341** above the opening section **1342***a*. The first plate-like sections are suspended by means of the plate section **1341** (or may also hang from the plate section) as a result of the retaining sections **1242***b* being engaged with the respective retaining holes **1342***d*. The first plate-like section **1242***a* slides in the vertical direction with respect to the front surface of the second plate-like section **1244**, whereby spacing between the first plate-like section **1242***a* and the second plate-like section **1244** varies.

The second plate-like section **1244** is a single plate-like member that is provided at the back side of the first plate-like sections **1242***a* of the respective first plate-like section units **1242-1** to **1242-9** and that assumes the shape of an elongated rectangle. Specifically, the second plate-like section **1244** is formed so as to become, in the horizontal direction, longer than a distance from a left lateral side of the first plate-like section **1242***a* of the first plate-like section unit **1242-1** provided at a left end to a right lateral side of the first plate-like section **1242***a* of the first plate-like section unit **1242-9** provided at a right end when viewed from the front. In addition, the second plate-like section **1244** is formed so as to have, in the vertical direction, (approximately) the same width as a vertical width of each of the first plate-like sections **1242**_a_ of the first plate-like section units **1242-1** to **1242-9**. The left end of the second plate-like section **1244** when viewed from the front is situated more left than the left lateral side of the first plate-like section **1242**_a_ of the first plate-like section unit **1242-1** and fixed to the plate section **1341** by means of the presser plate **1348**_a_. The right end of the second plate-like section **1244** when viewed from the front is situated more right than the right lateral side of the first plate-like section **1242**_a_ of the first plate-like section unit **1242-9** and fixed to the plate section **1341** by means of the presser plate **1348**_a_. Specifically, the second plate-like section **1244** is present on the back of each of the respective first plate-like section units **1242-1** to **1242-9** and in parallel with the respective first plate-like sections of the respective first plate-like section units **1242-1** to **1242-9**. The second plate-like section **1244** is formed from a substance unattracted by the magnet (a material to which the magnet does not adhere); that is, a non-magnetic substance, for instance, a film made from a synthetic resin. The second plate-like section **1244** can also be made from aluminum or stainless steel.

The second plate-like section **1244** is made larger than the opening section **1342**_a_ and provided so as to cover the opening section **1342**_a_ from the front.

The magnet section **1250** is formed from an electromagnet, and a leading end of the magnet section is formed so as to be placed in the opening section **1342**_a_ and contact the back side of the second plate-like section **1244**. A surface (facing the second plate-like section **1244**) of the leading end of the magnet section **1250** works as an attracting surface. The magnet section **1250** assumes a shape of an approximately cylindrical shape (the same also holds true for the magnet section **1270**). FIG. **33** to FIG. **35**, FIG. **38**, FIG. **39**, FIG. **42**, and FIG. **44** depict the magnet sections **1250** and **1270** while their detailed cross-sectional profiles are omitted. The magnet sections **1250** and **1270** are structurally similar to an ordinary electromagnet and include a core made of a magnetic substance and a coil wound around the core. When energized, the coil generates magnetic force. One magnet section **1250** is provided for the upstream grip section **1240**. The control circuit **90** activates the magnet section **1250**, whereupon the first plate-like section **1242**_a_ of any one of the first plate-like section units **1242-1** to **1242-9** corresponding to the position of the magnet section **1250** is attracted by the magnetic force. Spacing between the first plate-like section **1242**_a_ and the second plate-like section **1244** is thus closed. The magnet section **1250** is attached to an upper end of a front surface of a plate-like section **1360**_e_ in the supporting section **1360** in a direction perpendicular to a back side of the plate section **1341**. Specifically, the magnet section **1250** is secured in the direction of the arm **1312**.

When the respective first plate-like sections **1242**_a_ of the first plate-like section units **1242-1** to **1242-9** are viewed from the front, the guide members (first guide members) **1252** are provided above the respective first plate-like section units **1242-1** to **1242-9**, and the guide members (first guide members) **1254** are provided below the respective first plate-like section units **1242-1** to **1242-9**. As shown in FIG. **32**, the guide members **1252** and **1254** are arranged in such a way that the needle thread J diagonally passes on the back side of each of the first plate-like sections. Each of the guide members **1252** is provided at an upper left point above each of the first plate-like sections when viewed from the front. Each of the guide members **1254** is provided at a lower right point below each of the first plate-like sections when viewed from the front. A longer path can be assured for the needle thread J that is at the back side of each of the first plate-like sections, so that the needle thread J can be caught between the first plate-like sections and the second plate-like section **1244** in a more reliable manner.

The downstream grip section **1260** is placed on a lower area of the plate section **1341**; namely, an area below the turning section **1280**. The downstream grip section **1260** has the grip section main body (a downstream grip section main body) **1261** and the magnet section (a downstream actuation section or a downstream magnet section) **1270** provided at the back side of the grip section main body **1261**.

The grip section main body **1261** has the same structure as that of the grip section main body **1241**. The grip section main body **1261** has the first plate-like section units **1262-1** to **1262-9** provided for the respective needle bars and the second plate-like section (a downstream second plate-like section) **1264** that is provided at the back side of the first plate-like sections **1262**_a_ of the respective first plate-like section units **1262-1** to **1262-9** and on the front side of the needle bar case **1314** (specifically, the plate section **1341**).

The first plate-like section units **1262-1** to **1262-9** are structurally similar to the first plate-like section units **1242-1** to **1242-9**. As shown in FIG. **36**, each of the first plate-like sections **1262**_a_ of the first plate-like section units **1262-1** to **1262-9** includes the first plate-like section (a downstream first plate-like section) **1262**_a_ assuming the shape of a square-shaped plate and a retaining section (a mounting member) **1262**_b_ formed so as to project from an upper end of the first plate-like section **1262**_a_ to the back. The retaining section **1262**_b_ assumes the shape of an approximately-L-shaped plate. Specifically, each of the first plate-like section units **1262-1** to **1262-9** is formed from a material which is attracted by the magnet (a material to which the magnet adheres); that is, a magnetic substance (or a ferromagnetic substance instead). The respective first plate-like section units are formed in (or approximately) a same size and a same shape. As a result of the retaining sections **1262**_b_ being engaged with retaining holes **1342**_e_ formed in the plate section **1341**, the first plate-like section units **1262-1** to **1262-9** are arranged at spacing (specifically uniform intervals) side by side along the horizontal direction. Specifically, spacing exists between two adjacent first plate-like section units. The plurality of (specifically, a total of nine) retaining holes **1342**_e_ are arranged at spacings (specifically uniform intervals) side by side along the horizontal direction and at an area on the plate section **1341** above the opening section **1342**_c_ (and below the opening section **1342**_b_). The first plate-like sections are suspended by means of the plate section **1341** (or may hang from the plate section) as a result of the retaining sections **1262**_b_ being engaged with the respective retaining holes **1342**_e_. The first plate-like section **1262**_a_ slides in the vertical direction with respect to the front surface of the second plate-like section **1264**, whereby spacing between the first plate-like section **1262**_a_ and the second plate-like section **1264** varies. In relation to the first plate-like section units **1242-1** to **1242-9** and the first plate-like section units **1262-1** to **1262-9**, the first plate-like section units assigned to the same needle thread are placed at the same position with reference to the horizontal direction.

The second plate-like section **1264** is structurally similar to the second plate-like section **1244**. The second plate-like section **1264** is a single plate-like member that is provided on the back side of the first plate-like sections **1262**_a_ of the respective first plate-like section units **1262-1** to **1262-9**. Specifically, the second plate-like section **1264** is formed so as to become, in the horizontal direction, longer than a distance from a left lateral side of the first plate-like section **1262***a* of the first plate-like section unit **1262-1** provided at a left end to a right lateral side of the first plate-like section **1262***a* of the first plate-like section unit **1262-9** provided at a right end when viewed from the front. In addition, the second plate-like section **1264** is formed so as to have, in the vertical direction, (or approximately) the same width as a vertical width of each of the first plate-like sections **1262***a* of the first plate-like section units **1262-1** to **1262-9**. The left end of the second plate-like section **1264** when viewed from the front is situated more left than the left lateral side of the first plate-like section **1262***a* of the first plate-like section unit **1262-1** and fixed to the plate section **1341** by means of the presser plate **1348***b*. The right end of the second plate-like section **1264** when viewed from the front is situated more right than the right lateral side of the first plate-like section **1262***a* of the first plate-like section unit **1262-9** and fixed to the plate section **1341** by means of the presser plate **1348***b*. Specifically, the second plate-like section **1264** is present at a back side of each of the first plate-like sections of the respective first plate-like section units **1262-1** to **1262-9** and in parallel with the respective first plate-like sections of the respective first plate-like section units **1262-1** to **1262-9**. The second plate-like section **1264** is formed from a material unattracted by the magnet (a material to which the magnet does not adhere); that is, a non-magnetic substance.

The second plate-like section **1264** is made larger than the opening section **1342***c* and provided so as to cover the opening section **1342***c* from the front.

Like the magnet section **1250**, the magnet section **1270** is formed from an electromagnet, and a leading end of the magnet section is formed so as to be placed in the opening section **1342***c* and contact the back side of the second plate-like section **1264**. A surface (facing the second plate-like section **1264**) of the leading end of the magnet section **1270** works as an attracting surface. One magnet section **1270** is provided for the downstream grip section **1260** and formed in (or approximately) the same size and the same shape as that of the magnet section **1250**. The control circuit **90** activates the magnet section **1270**, whereupon the first plate-like section **1262***a* of any one of the first plate-like section units **1262-1** to **1262-9** corresponding to the position of the magnet section **1270** is attracted by the magnetic force. Spacing between the first plate-like section **1262***a* and the second plate-like section **1264** is thus closed. The magnet section **1270** is attached to a lower end of a front surface of the plate-like section **1360***e* in the supporting section **1360** in a direction perpendicular to a back side of the plate section **1341**, thereby being secured in the direction of the arm **1312**.

The magnet section **1250** and the magnet section **1270** are placed at the same position with reference to the horizontal direction. When the magnet section **1250** and the magnet section **1270** are activated, the magnet sections grip the same needle thread. For instance, in the example shown in FIG. **30**, FIG. **31**, FIG. **33**, FIG. **34**, and FIG. **35**, the magnet section **1250** is situated at the back side of the first plate-like section of the first plate-like section unit **1242-8**, and the magnet section **1270** is situated at the back side of the first plate-like section of the first plate-like section unit **1262-8**. Therefore, the magnet sections **1250** and **1270** grip the same thread.

When the respective first plate-like sections **1262***a* of the first plate-like section units **1262-1** to **1262-9** are viewed from the front, the guide members (second guide members) **1272** are provided above the respective first plate-like section units **1262-1** to **1262-9**, and the guide members (second guide members) **1274** are provided below the respective first plate-like section units **1262-1** to **1262-9**. As shown in FIG. **32**, the guide members **1272** and **1274** are arranged in such a way that the needle thread J diagonally passes at the back side of each of the first plate-like sections. Each of the guide members **1272** is provided at an upper left point above each of the first plate-like sections when viewed from the front. Each of the guide members **1274** is provided at a lower right point below each of the first plate-like sections when viewed from the front. A longer path can be assured for the needle thread J that is at the back side of each of the first plate-like sections, so that the needle thread J can be caught between the first plate-like sections and the second plate-like section **1264** in a more reliable manner.

The turning section **1280** is placed at an intermediate position between the upstream grip section **1240** and the downstream grip section **1260** along the vertical direction. More specifically, the turning section **1280** is disposed at a downstream position in the direction in which the upstream grip section **1240** feeds a needle thread and an upstream position in the direction in which the downstream grip section **1260** feeds a needle thread. The turning section **1280** is for turning the needle thread between the grip section main body **1241** and the grip section main body **1261** (or an area (a position) of the needle thread located between the grip section main body **1241** and the grip section main body **1261**).

The turning section **1280** has the turning arm **1281** and a needle thread motor **1286** for rotating the turning arm **1281**. As shown in FIG. **31**, FIG. **33**, FIG. **34**, and FIG. **35**, the turning arm **1281** has a rod-shaped main body section **1282** and a hook section **1289** provided at one leading end of the main body section **1282**. An output shaft **1286***a* of the needle thread motor **1286** is fastened to the other leading end of the main body section **1282**. Specifically, when viewed sideways, the output shaft is arranged in such a way that the center axis of the output shaft **1286***a* of the needle thread motor **1286** passes through the center axis of the main body section **1282**. The hook section **1284** assumes a (or approximately) circular-arc rod shape and is arranged so as to enable the hook section **1284** to hook the needle thread J as a result of turning of the turning arm **1281**. Specifically, the hook section **1284** is structured so as to be able to contact and retain the needle thread J laid in parallel to the axis line of the output shaft **1286***a* of the needle thread motor **1286** as a result of the turning arm **1281** being upwardly turned around the output shaft **1286***a* (more specifically, an axis line (a rotating center) of the output shaft **1826***a*) of the needle thread motor **1286**. The turning arm **1281** is interposed between the magnet section **1250** and the magnet section **1270** and at the same position where the magnet sections **1250** and **1270** are placed with reference to the horizontal direction; and can retain a selected needle thread.

The needle thread motor **1286** is secured to L-shaped hardware **1360***f*, thereby being secured in the direction of the arm **1312**. When the needle thread motor **1286** rotates, the turning arm **1281** is turned upward from the receded position (a position **1281**(B) shown in FIG. **34** and FIG. **35**) that is obliquely downward on the front, to thus project to the front from the opening section **1342***b* of the plate section **1341**. A direction of the output shaft **1286***a* of the needle thread motor **1286** (a direction of an axis line of the output shaft **1286***a*) lies in a horizontal direction (namely, a direction parallel with the back surface of the plate section **1341** and along the horizontal direction). The needle thread motor is configured in such a way that, when the turning arm **1281** is situated at the receded position, the turning arm **1281** will not contact the plate section **1341** or any member provided on the plate section **1341** (e.g., the needle thread supporting member **1288**, the guide member **1346***b*, or the like) even if the needle bar case **1314** slides in the horizontal direction. Specifically, the receded position is a position where the turning arm **1281** will not contact the needle bar case **1314** (in particular, the plate section **1341** and any member provided on the plate section **1341**) even if the needle bar case **1314** slides in the horizontal direction; at least, a position achieved as a result of the turning arm **281** having turned lower than a position where the turning arm **1281** contacts the needle thread supported by the needle thread supporting member **1288** and also a position where the leading end of the turning arm **1281** will not reach the opening section **1342***b*.

The needle thread supporting members **1288** are placed on both sides of each of the opening sections **1342***b* of the plate section **1341** so as to front on both interior sides of the opening section. Specifically, each of the needle thread supporting members **1288** is made by folding back a wire into a circular-arc shape. The pair of needle thread supporting members **1288** assume the same structure.

Each of the needle thread supporting members **1288** includes a base end section **1288***a*; a circular-arc member **1288***b* formed so as to extend continually from a lower end of the base end section **1288***a*; a connecting member **1288***c* formed so as to extend continually from an end of the circular-arc member **1288***b* that is on its other side with respect to the base end section **1288***a*; and a circular-arc member **1288***d* formed so as to extend continually from an end of the connecting member **1288***c* that is on its other side with respect to the circular-arc member **1288***b*. The needle thread supporting member **1288** is formed integrally from a wire.

The base end section **1288***a* is formed into a vertically-oriented straight line. An upper end of the base end section **1288***a* is attached to a position above the opening section **1342***b* on the back side of the plate section **1341**. The circular-arc member **1288***b* is formed (or approximately) concentrically with the rotating center of the needle thread motor **1286** so as to face the opening section **1342***b*. The circular-arc member **1288***b* except its portion is provided in the opening section **1342***b*. The connecting member **1288***c* is formed into an approximately circular-arc shape. A front-side end of the connecting member **1288***c* projects to the front side with reference to the front surface of the plate section **1341**. A remaining portion of the connecting member **1288***c* is provided in the opening section **1342***b*. The circular-arc member **1288***d* is formed on a side of the circular-arc member **1288***b* that is on its other side with respect to the axis line (an axis line passing through the rotating center) of the output shaft of the needle thread motor **1286**, approximately in parallel with the circular-arc member **1288***b*, and (approximately) concentrically with the rotating center of the needle thread motor **1286**. An upper end of the circular-arc member **1288***d* is curved to the front. The circular-arc section **1288***d* projects to the front with reference to the front surface of the plate section **1341**. When viewed sideways, the circular-arc member **1288***b* and the circular-arc member **1288***d* are formed concentrically with the rotating center of the needle thread motor **1286**. In one of the needle thread supporting members **1288**, the circular-arc member **1288***b* and the circular-arc member **1288***d* are formed along a plane perpendicular to an axis line of the output shaft of the needle thread motor **1286** (i.e., an axis line passing through the rotating center) while spaced apart from each other in a direction perpendicular to the axis line of the output shaft. In one needle thread supporting member **1288**, the circular-arc member **1288***b* and the circular-arc member **1288***d* are formed at the same position with reference to the horizontal direction. Further, the pair of needle thread supporting members **1288** provided for one needle thread are provided while spaced apart from each other in the horizontal direction. The connecting member **1288***c* connects a lower end of the circular-arc member **1288***b* and a lower end of the circular-arc member **1288***d*.

A needle thread is inserted into spacing between the circular-arc member **1288***b* and the circular-arc member **1288***d* from above the pair of needle thread supporting members **1288**, to thus be positioned between the pair of connecting members **1288***c*. The needle thread J can thereby be placed between the pair of connecting members **1288***c* with respect to the horizontal direction. Even when the turning arm **1281** upwardly draws the needle thread J, the needle thread J stays at the spacing between the circular-arc member **1288***b* and the circular-arc member **1288***d*. Namely, the needle thread supporting members **1288** support the needle thread at the position of the opening section **1342***b* [namely, the position of the opening section **1342***b* in both the vertical and horizontal directions (specifically, a position beneath the opening section **1342***b*)] in the horizontal direction; more specifically, toward the front side of the opening section **1342***b* (or "a position on the front side of the opening section **1342***b*") in the horizontal direction when viewed from the front. The needle thread supporting members **1288** can also support the needle thread within the opening section **1342***b* with respect to the horizontal direction (namely, a position between the front surface and back surface of the plate section **1341** with respect to the front-back direction).

The rod-shaped guide member (a first needle thread path inverting member) **1290** for guiding the needle thread J fed from above (in other words; from the upstream grip section **1240**) to the needle thread supporting member **1288** is secured to a position in the vicinity of a lower side of each of the opening sections **1342***b* and on the front side of the plate section **1341**. The guide member **1290** inverts the needle thread guided from above and subsequently leads the needle thread to the needle thread supporting member **1288**.

The supporting section **1360** is mounted on the upper surface section **1312***a* of the arm **1312**. The supporting section **1360** includes L-shaped hardware **1360***a* mounted on the arm **1312**; L-shaped hardware **1360***b* secured to the L-shaped hardware **1360***a*; a rod-shaped plate section **1360***c* secured to the L-shaped hardware **1360***b*; L-shaped hardware **1360***d* secured to the rod-shaped plate section **1360***c*; the plate-like section **1360***e* secured to the L-shaped hardware **1360***d*; and the L-shaped hardware **1360***f* secured to the front surface of the plate-like section **1360***e*.

The plate-like section **1360***e* is provided in (or approximately) parallel with the plate section **1341**. One plate-like section **1360***f*-**1** of the L-shaped hardware **1360***f* is secured to the plate-like section **1360***e*, whilst another plate-like section **1360***f*-**2** standing upright on the plate-like section **1360***f*-**1** is provided at right angles to the plate-like section **1360***e*. The plate-like section **1360***f*-**2** thereby becomes perpendicular to the plate section **1341**. One plate-like section **1360***d*-**1** of the L-shaped hardware **1360***d* is secured to the plate-like section **1360***e*. A remaining plate-like section **1360***d*-**2** standing on the plate-like section **1360***d*-**1** is provided at right angles to the plate section **1341**.

There can also be adopted another configuration in which the supporting section **1360** is taken as a portion of constituent elements of the arm **1312**; in which the arm **1312** is taken as an arm main body; and in which the arm has an arm main body and the supporting section **1360**.

The control circuit **90** is a circuit for controlling operation of the main spindle motor **20**, operation of the needle thread motor **1286**, operation of the magnet section **1250**, and operation of the magnet section **1270**. According to the data stored in the memory device **92**, the control circuit **90** controls operation of the individual sections. Specifically, the control circuit **90** generates main spindle data (see FIG. **7**) according to embroidery data read from the memory device **92** and controls operation of the main spindle motor **20** according to the thus-generated main spindle data.

According to the embroidery data read from the memory device **92**, the control circuit **90** generates needle thread control torque data (see FIG. **9**). In the torque control zone, the needle thread motor **1286** is subjected to torque control in accordance with the needle thread control torque data. In a position control zone, the control circuit **90** generates angle correspondence data, such as that shown in FIG. **15**, and performs position control in accordance with the angle correspondence data.

In a zone ranging from the endpoint of the position control zone to the end point of the torque control zone, the control circuit **90** controls the magnet sections **1250** and **1270** so as to close the upstream grip section **1240** and open the downstream grip section **1260**. In the meantime, in a zone ranging from the endpoint of the torque control zone to the end point of the position control zone, the control circuit **90** controls the magnet sections **1250** and **1270** so as to open the upstream grip section **1240** and close the downstream grip section **1260**.

Specifically, as shown in FIG. **5**, the control circuit **90** has the CPU **90***a*, the PWM circuit **90***b*, and the current sensor **90***c* in the same manner as in the first and second embodiments. The respective sections; namely, the CPU **90***a*, the PWM circuit **90***b*, and the current sensor **90***c*, are structurally analogous to their counterparts described in connection with the first and second embodiments, and hence their repeated detailed descriptions are omitted. In the third embodiment, the solenoid **50** shown in FIG. **5** is replaced by the magnet section **1250**, and the solenoid **70** is replaced by the magnet section **1270**.

The encoder **21** for detecting an angle of the main spindle motor **20** (the rotational position of the main spindle motor **20**) is interposed between the main spindle motor **20** and the control circuit **90**. An encoder **1287** for detecting an angle of the needle thread motor **1286** (a rotational position of the needle thread motor **1286**) is interposed between the needle thread motor **1286** and the control circuit **90**. The control circuit **90** detects angles of the respective motors (the rotational positions of the respective motors) from information output from the respective encoders.

The shuttle **12***c* is placed at a position that is beneath the head **1207** and lower than the upper surface of the sewing machine table; specifically, the shuttle **12***c* is supported by the shuttle base (not shown) disposed below the sewing machine table.

The sewing frame **12***d* is a member for holding the processed fabric in a stretched manner and placed above (or on an upper surface of) the sewing machine table.

The main spindle **22** is rotated by the main spindle motor **20**, and rotating force is transmitted by a predetermined power transmission mechanism, thereby actuating respective machine elements, such as the thread take-up levers **12***a***-1** to **12***a***-9**, the needle bars **12***b***-1** to **12***b***-9**, and presser feet, and the shuttle **12***c*. The main spindle motor **20** is configured so as to rotate in one direction. In the case of a multi-head embroidery sewing machine having a plurality of heads, a main spindle common to the respective heads is provided, and the main spindle motor for rotating the main spindle is provided.

The frame actuator **24** is for actuating the sewing frame **12***d* in both the X-axis direction (direction **X1**-**X2**) and the Y-axis direction (direction **Y1**-**Y2**) in accordance with a command from the control circuit, and actuates the sewing frame **12***d* in synchronism with vertical movements of the needle bar **12***b*. Specifically, the frame actuator **24** is made up of a servo motor for actuating the sewing frame **12***d* in the X-axis direction, a servo motor for actuating the sewing frame **12***d* in the Y-axis direction, and others.

The memory device **92** stores embroidery data used for performing embroidery. The embroidery data here mean; for instance, data that pertain to a stitch width, a stitching direction, a thread type (which one of a plurality of types of threads is used), and thread attributes (a thread material and a thread thickness), and that are provided for each stitch.

As shown in FIG. **6**, the memory device **92** stores data pertaining to the starting point and the endpoint of the torque control zone as information about a main spindle angle in the same manner as in the first embodiment, and also data pertaining to the starting point and the end point of the position control zone as information about a main spindle angle. The starting point and the endpoint of the torque control zone and the starting point and the end point of the position control zone are the same as those described in connection with the first embodiment, and hence their detailed explanations are omitted.

An explanation is now given to the path of the needle threads J. Nine needle threads run along similar paths. Therefore, the needle thread situated at the right end when viewed from the front is taken as an example. The needle thread J guided from a thread roll (not shown) contacts the guide member **1252** by way of the needle thread guide **1300**; passes through spacing between the first plate-like section of the first plate-like section unit **1242-9** and the second plate-like section **1244** of the upstream grip section **1240**, then contacts the guide member **1254**, undergoes inversion on the guide member **1290**, and subsequently reaches the needle thread supporting member **1288**. The needle thread J passed through the pair of needle thread supporting members **1288** contacts the guide member **1272**, passes through spacing between the first plate-like section of the first plate-like section unit **1262-9** and the second plate-like section **1264** of the downstream grip section **1260**, then contacts the guide member **1274**. In addition, the needle thread J reaches the thread take-up lever **12***a***-9** by way of the needle thread guide **1302** and the tension spring **1337** and further reaches a sewing needle of the needle bar **12***b***-9** from the thread take-up lever **12***a***-9** by way of the needle thread guide **1338**. The needle thread travels from the upstream side to the downstream side along the sequence mentioned above.

Operation of the sewing machine **1205** having the above structure is now described. First, operation of the needle thread motor **1286** and operation of the magnet sections **1250** and **1270** are described.

First, the control circuit **90** generates main spindle data (see FIG. **7**) for each stitch in accordance with the embroidery data stored in the memory device **92** as in the case of the second embodiment. The method under which the control circuit **90** generates main spindle data is the same as that described in connection with the second embodiment, and hence its detailed explanations are omitted here for brevity.

In accordance with the embroidery data stored in the memory device **92**, the control circuit **90** generates for each stitch needle thread control torque data used for controlling torque of the needle thread motor **1286** as in the case of the second embodiment (see FIG. **9**). The method for generating the needle thread control torque data is the same as that described in connection with the second embodiment, and hence its detailed explanation is omitted here for brevity.

Operation performed during actual embroidering is analogous to that described in connection with the second embodiment. The sewing machine operates according to a flowchart shown in FIGS. **10** to **13** and FIG. **17**. However, in the third embodiment, a plurality of needle bars are provided, and an arbitrary needle bar is selected from the plurality of needle bars (i.e., a thread is selected). Accordingly, a main spindle angle is detected along the flowchart shown in FIG. **10** (S**1**). When the detected main spindle angle is a main spindle angle corresponding to a start of one stitch (e.g., a zero degree in FIG. **18**) (namely, on the occasion of transition to the next stitch) and when a needle thread to be selected is subjected to a change, there is performed the following processing between step S**1** and step **32**; namely, processing for sliding the needle bar case **1314**, to thereby place the magnet sections **1250** and **1270** at the position of the thus-selected thread and letting the turning arm **1281** come to the position of the opening section **1324** corresponding to the selected needle thread so that the turning arm **1281** of the turning section **1280** can retain and pull up the needle thread.

When the needle bar case **1314** slides with respect to the arm **1312**, the turning arm **1281** is downwardly turned to the receded position designated by **1281**(B) in FIG. **34** and FIG. **35**, to thus prevent the turning arm **1281** from contacting the plate section **1314** and a member provided on the plate section **1314**.

Even in the torque control subroutine pertaining to step S**3** shown in FIG. **10**, operation is performed along the flowchart shown in FIG. **11** in the same way as described in connection with the first and second embodiments.

Even in the position control subroutine pertaining to step S**5** shown in FIG. **10**, operation is performed in the same way as indicated by flowcharts illustrated in FIGS. **12** and **13** as in the case of the first embodiment.

Even in relation to control of switching between the upstream grip section **1240** and the downstream grip section **1260**, the following operation is performed in the same manner as in the case of the first and second embodiments as shown in FIG. **17** and FIG. **18**. Specifically, the grip section main body **1241** of the upstream grip section **1240** is opened, and the grip section main body **1261** of the downstream grip section **1260** is closed from the end point of the torque control zone to the end point of the position control zone of the needle thread motor **1286**. In the meantime, the grip section main body **1241** of the upstream grip section **1240** is closed, and the grip section main body **1261** of the downstream grip section **1260** is opened from the end point of the position control zone to the end point of the torque control zone. When the grip section main bodies **1241** and **1261** are closed, the gripped needle thread is fixed. On the contrary, when the grip section main bodies **1241** and **1261** are opened, the needle thread is released from the gripped state.

As a result of activation of the magnet section **1250**, the first plate-like section of the first plate-like section unit corresponding to the position of the magnet section **1250**, among the first plate-like section main units **1242-1** to **1242-9**, is attracted by magnetic force. Spacing between the first plate-like section **1242***a* and the second plate-like section **1244** is thereby closed tightly, and the grip section main body **1241** is also closed. Thus, there is achieved a closed state in which the needle thread J is pinched between the first plate-like section **1242***a* and the second plate-like section **1244**. As shown in; for instance, FIGS. **31**, **34**, and **35**, when the magnet section **1250** is situated on the back side of the first plate-like section **1242***a* of the first plate-like section unit **1242-8**, the magnet section **1250** is activated, whereby the spacing between the first plate-like section **1242***a* and the second plate-like section **1244** is tightly closed. Thus, the needle thread is gripped between the first plate-like section **1242***a* and the second plate-like section **1244**. When the magnet section **1250** is not activated, the spacing between the first plate-like section **1242***a* and the second plate-like section **1244** is not tightly closed (namely, the first plate-like section and the second plate-like section remain in simple contact with each other). Hence, the grip section main body **1241** is opened, thereby achieving an open state in which the needle thread is released. As above, the magnet section **1250** acting as the upstream drive section switches between the closed state in which the grip section main body **1241** grips the needle thread and the open state in which the needle thread is released.

Likewise, as a result of activation of the magnet section **1270**, the first plate-like section of the first plate-like section unit corresponding to the position of the magnet section **1270**, among the first plate-like sections **1262-1** to **1262-9**, is attracted by magnetic force. Spacing between the first plate-like section **1262***a* and the second plate-like section **1264** is thereby tightly closed, and the grip section main body **1261** is also closed. Thus, there is achieved a closed state in which the needle thread J is pinched between the first plate-like section **1262***a* and the second plate-like section **1264**. As shown in; for instance, FIG. **31**, FIG. **34**, and FIG. **35**, when the magnet section **1270** is situated on the back side of the first plate-like section **1262***a* of the first plate-like section unit **1262-8**, the magnet section **1270** is activated, whereby the spacing between the first plate-like section **1262***a* and the second plate-like section **1264** is tightly closed. Thus, the needle thread is gripped between the first plate-like section **1262***a* and the second plate-like section **1264**. When the magnet section **1270** is not activated, the spacing between the first plate-like section **1262***a* and the second plate-like section **1264** is not tightly closed (specifically, the first plate-like section and the second plate-like section remain in simple contact with each other). Hence, the grip section main body **1261** is opened, thereby achieving an open state in which the needle thread is released. As above, the magnet section **1270** acting as the upstream drive section switches between the closed state in which the grip section main body **1261** grips the needle thread and the open state in which the needle thread is released.

Specifically, an explanation is given to operation of the needle thread control section **1230**. When the main spindle angle is at the end point of the position control zone, the turning arm **1281** assumes a position of the top dead center (the initial position). Specifically, the hook section **1284** of the turning arm **1281** is situated at an obliquely upward position (a position designated by **1281**(A) shown in FIG. **34** and FIG. **35**). The leading end of the turning arm **1281** is exposed to the front side of the plate section **1341** from the opening section **1342***b* at the initial position. When a change is made to the needle thread to be selected, the turning arm **1281** is receded. Therefore, the turning arm **1281** is turned to the receded position. On this occasion, the turning arm **1281** is downwardly turned, thereby turning the needle thread to the receded position.

When entered the torque control zone, the needle thread motor **1286** is subjected to torque control while the grip section main body **1241** is closed and while the grip section main body **1261** is opened, whereby the needle thread motor **1286** imparts upward rotating force to the turning arm **1281**. Thereby, the thread take-up lever **12***a***-1**, or the like, turns upwardly while the turning arm **1281** is pulling the needle thread J against a direction (a pulling direction) in which the thread take-up lever **12***a***-1**, or the like, pulls the needle thread J, thereby pulling the needle thread J with respect to the processed fabric. As the thread take-up lever **12**a-**1**, or the like, pulls the needle thread J (i.e., the thread take-up lever **12**a shifts to the top dead center (the other dead center)), the turning arm **1281** turns in the direction (the downward direction) in which the thread take-up lever **12**a-**1**, or the like, pulls the needle thread J.

As in the case of the first and second embodiments, a torque value set in the needle thread control torque data is set to a value such that, as the thread take-up lever **12**a-**1**, or the like, pulls the needle thread J, the turning arm **1281** turns in the direction (the downward direction) in which the thread take-up lever **12**a-**1**, or the like, pulls the needle thread J and does not hinder the thread take-up lever **12**a from pulling the needle thread J.

When the main spindle angle enters the position control zone, the needle thread motor **1286** is subjected to position control while the grip section main body **1241** is opened and while the grip section main body **1261** is closed, whereupon the turning arm **1281** turns in a direction (an upward direction) in which the needle thread J is pulled. Reference numeral **1281**(A) shown in FIG. **34** and FIG. **35** shows a state where the turning arm **1281** turned to its initial position (or a position of origin) as a result of the needle thread motor **1286** having returned to the initial position at the end point of the position control zone.

When the torque value is large, the needle thread J is hardly pulled during torque control, so that a stitch is tightly sewn. On the contrary, when the torque value is small, the needle thread J is weakly pulled, so that a corresponding stitch is softly sewn.

As above, in connection with a control zone for each stitch, in a torque control zone including at least a portion of an area from the bottom dead center to the top dead center of the thread take-up lever **12**a-**1**, or the like, that is a zone during which the thread take-up lever **12**a-**1**, or the like, pulls the needle thread with respect to the processed fabric to be sewn with the needle thread, there is performed torque control for imparting rotating force to the turning arm **1281** in accordance with the torque value in such a way that tension is imparted to the needle thread against the direction in which the thread take-up lever **12**a-**1**, or the like, pulls the needle thread, while the grip section main body **1241** is closed and while the grip section main body **1261** is opened, in the meantime, in a position control zone that is at least a portion of the zone other than the torque control zone, there is performed position control for imparting rotating force to the turning arm **1281** in accordance with angular position data pertaining to the needle thread motor **1286** in such a way that the angle of the needle thread motor **1286** returns to its initial angular position which is a rotational position of the needle thread motor **1286**, while the grip section main body **1241** is opened and while the grip section main body **1261** is closed, thereby drawing the needle thread from upstream.

Control of the main spindle motor **20** is analogous to that described in connection with the first embodiment. The main spindle motor **20** operates along the flowcharts shown in FIGS. **21** and **22**. However, in the third embodiment, a plurality of needle bars are provided, and an arbitrary needle bar is selected from the plurality of needle bars (i.e., a thread is selected) as in the case of the second embodiment. On the occasion of the main spindle angle being read from the main spindle data in step S**51** of the flowchart shown in FIG. **21**, when the main spindle angle corresponds to the start of one stitch (e.g., zero degree in FIG. **18**) and when a needle thread to be selected is changed, there is performed the following processing between steps S**51** and S**52**; namely, processing for sliding the needle bar case **1314**, to thereby place the magnet sections **1250** and **1270** at the position of the thus-selected thread, and letting the turning arm **1281** come to the position of the opening section **1342**b corresponding to the selected needle thread so that the turning arm **1281** of the turning section **1280** can retain and pull up the thus-selected thread.

Control of the main spindle motor **20** is analogous to that described in connection with the first embodiment except that control of sliding operation of the needle bar case **1314** is provided and, therefore, its detailed explanations are omitted.

As mentioned above, in the sewing machine of the third embodiment, the needle thread is subjected to torque control in the torque control zone. Accordingly, the magnitude of tension on the needle thread can be controlled. In particular, torque control can be performed on a per-stitch basis in the torque control zone by means of the needle thread control torque data (FIG. **9**). Hence, tension on the needle thread can be controlled on a per-stitch basis, so that seam hardness can be controlled on a per-stitch basis.

In the case of the multi-needle head, even when a stitch is formed from a different needle thread, a torque value in the needle thread control torque data is made constant, whereby tension on the needle thread can be equally controlled. In the case of a multi-head embroidery sewing machine, the needle thread control torque data used for a torque control zone are made common to the heads, whereby tension on the needle threads exerted by the respective heads can be made equal.

Further, the needle thread control section **1230** is provided in place of the tension disc and the rotary tension component in the related-art sewing machine (see FIG. **47**). In the position control zone where the needle thread J is drawn, the grip section main body **1241** becomes open, and only the needle thread guide **1300** is present at an upstream position with respect to the turning arm **1281** of the turning section **1280**. Frictional resistance does not exist between the tension disc and the rotary tension component. Further, the grip section main body **1261** becomes closed. Hence, movements of the thread take-up lever **12**a will not pose any problem when the needle thread is drawn. Consequently, the needle thread can be smoothly drawn from the thread roll, thereby reducing the risk of occurrence of a thread break.

In contrast to the related-art sewing machine shown in FIG. **48**, the sewing machine **1205** can be configured as follows. Namely, the needle thread control mounting section **1340** having the grip section main bodies **1241** and **1261** and the needle thread supporting member **1288** is provided on the needle bar case main body **1330** in place of the needle thread adjustment member mounting section **2340** having the tension disc **95**, the rotary tension component **94**, and the needle thread guides **1300** and **1302**. The magnet sections **1250** and **1270** and the turning section **1280** are attached to the arm **1312** by way of the supporting section **1360**. The configuration of the present embodiment is adopted as the configuration of the control circuit **90** and that of the memory section **92**. The configuration of the related-art sewing machine can be employed for the configuration of the head except its members to be replaced with their counterpart members in the related-art sewing machine; in particular, the arm **1312** and its internal configuration and the needle bar case main body **1330** and its internal configuration. Therefore, manufacturing cost can be curtailed.

If a break has occurred in a needle thread, the turning arm **1281** will not turn downwardly in the torque control zone. Specifically, the turning arm **1281** will not pulled in the downward direction that is opposite to the direction in which the rotating force of the needle thread motor **1286** is imparted. A thread break can be detected by detecting that the turning arm

1281 does not turn downwardly. Further, when there are not any thread breaks, the turning arm 1281 downwardly turns in the torque control zone. Hence, occurrence of a thread break can be detected accurately.

In the position control zone, the current position (angle) of the needle thread motor 1286 is detected. There are generated angle correspondence data for controlling the position of the needle thread motor 1286 to its initial angle position. There is performed control for returning the needle thread motor 1286 to its initial position in accordance with the angle correspondence data through position control. Accordingly, the needle thread can be drawn by only the amount corresponding to a quantity of thread consumed as a result of pulling of the turning arm 1281 in the torque control zone. Hence, an excess or deficiency of the quantity of accumulated thread, which would otherwise be caused by pulling a needle thread, will not occur.

When the structure including the upstream grip section 1240, the downstream grip section 1260, and the turning section 1280 is applied to the multi-needle head, the sewing machine can be configured by providing only one each of the magnet section 1250 of the upstream grip section 1240, the magnet section 1270 of the downstream grip section 1260, and the turning section 1280. Accordingly, the sewing machine can be provided with an efficient structure while its manufacturing cost is curtailed.

Fourth Embodiment

A sewing machine of a fourth embodiment is now described. Although the sewing machine of the fourth embodiment has a similar structure as that of the sewing machine described in connection with the third embodiment, they differ from each other in a configuration that supports the magnet sections 1250 and 1270 and the turning section 1280.

The sewing machine of the fourth embodiment is described by reference to FIG. 37 and FIG. 38. A slide assist member 1350 is secured to a back surface of the plate section 1341 in the needle thread control mounting section 1340. A slide assist member 1352 is secured to an upper surface of the needle bar case main body, 1330. FIG. 38 is a principal cross sectional view in which only the needle thread control mounting section 1340 and the needle thread control section 1230 are fractured at position P-P shown in FIG. 32. FIG. 38 shows them while omitting needle threads.

Specifically, the slide assist member 1350 is disposed at an upper end area on the back surface of the plate section 1341 and made up of an L-shaped plate-like section. Specifically, the slide assist member 1350 has a plate-like section 1350*a* that forms a right angle with the back surface of the plate section 1341 and that is provided in the horizontal direction and a plate-like section 1350*b* that is downwardly formed so as to extend continually from an end of a back side of the plate-like section 1350*a*. Both the plate-like section 1350*a* and the plate-like section 1350*b* assume a rectangular shape, and the plate-like section 1350*b* is provided in parallel with the plate section 1341.

The slide assist member 1352 has a plate-like section 1352*a* that is secured to the upper surface of the needle bar case main body 1330 in the horizontal direction and a plate-like section 1352*b* formed at an end on a back side of the plate-like section 1352*a* in an obliquely upward direction. Both the plate-like section 1352*a* and the plate-like section 1352*b* assume a rectangular shape, and the plate-like section 1352*b* is disposed in parallel with the plate like section 1341. A distance between the plate-like section 1352*b* and the plate section 1341 and a distance between the plate-like section 1350*b* and the plate section 1341 are formed so as to become equal to each other. Aback surface of the plate-like section 1350*b* and a back surface of the plate-like section 1352*b* lie in the same plane. The plate-like section 1350*a*, the plate-like section 1350*b*, the plate-like section 1352*a*, and the plate-like section 1352*b* are formed to the same thickness.

A lower-end side of the plate-like section 1350*b* and an upper-end side of the plate-like section 1352*b* act as rails along which a supporting section 1370 slides in the horizontal direction.

The slide assist member 1352 is placed on the upper surface of the needle bar case main body 1330. However, the mount position of the slide assist member 1352 is not limited to the upper surface but can also be secured to the back surface of the plate section 1341. Alternatively, side surface sections for connecting the slide assist member 1350 to the slide assist member 1352 can also be provided on both sides of each of the slide assist members 1350 and 1352, thereby integrating the slide assist members 1350 and 1352 into one. The thus-integrated slide assist members 1350 and 1352 can also be provided on an upper surface of the needle bar case main body 1330.

The supporting section (a magnet section/motor supporting member) 1370 is a member for supporting the magnet sections 1250 and 1270 and the turning section 1280. The supporting section 1370 includes a plate-like section 1372, L-shaped hardware 1374 secured to a front surface of the plate-like section 1372, and L-shaped hardware 1376 secured to a back surface of the plate-like section 1372.

Specifically, the plate-like section 1372 assumes the shape of a rectangular plate. A vertical length L1 of the plate-like section 1372 is made longer than a length L2 from a lower end of the plate-like section 1350*b* to an upper end of the plate-like section 1352*b*. Wheel sections 1373 are provided respectively at four corners of a back surface of the plate-like section 1372 so as to be rotatable with respect to the plate-like section 1372. Each of the wheel sections 1373 has a pair of disc sections 1373*a* spaced apart from each other and a cylindrical section 1373*b* placed between the pair of disc sections 1373*a*. The cylindrical section 1373*b* is formed so as to be rotatable with respect to a shaft section 1373*c* secured to the plate-like section 1372. A lower end of the plate-like section 1350*b* is situated between the pair of disc sections 1373*a* of the upper two wheel sections 1373. A lower end of the plate-like section 1350*b* remains in contact with the cylindrical section 1373*b*. An upper end of the plate-like section 1352*b* is situated between the pair of disc sections 1373*a* of the lower two wheel sections 1373, and an upper end of the plate-like section 1352*b* remains in contact with the cylindrical section 1373*b*. As a result of the plate-like section 1372 being slid in the horizontal direction, the wheel sections 1373 rotate along the plate-like sections 1350*b* and 1352*b*, and the supporting section 1370 smoothly slides in the horizontal direction. The plate-like section 1372 is in parallel with the plate section 1341.

One plate-like section 1374-1 of the L-shaped hardware 1374 is secured to the plate-like section 1372. Another plate-like section 1374-2 provided upright on the plate-like section 1374-1 is provided at right angles to the plate-like section 1374-1. The plate-like section 1374-2 is at right angles to the plate section 1341. One plate-like section 1376-1 of the L-shaped hardware 1376 is secured to the plate-like section 1372, and another plate-like section 1376-2 standing upright on the plate-like section 1376-1 extends continually from a lower end of the plate-like section 1376-1 and is provided on the level. A groove section **1376-2***a* to be engaged with a rod-shaped plate section **1380***c* is formed in the plate-like section **1376-2**.

A slide regulation section **1380** is provided on the upper surface section **1312***a* of the arm **1312**. The slide regulation section **1380** has L-shaped hardware **1380***a* attached onto the arm **1312**, L-shaped hardware **1380***b* secured to the L-shaped hardware **1380***a*, and a rod-shaped section **1380***c* secured to the L-shaped hardware **1380***b*. As shown in FIG. **37**, a horizontally elongated hole **1380***a***-1** is formed in the plate-like upright section of the L-shaped hardware **1380***a*. A bolt **1380***b***-1** attached to the L-shaped hardware **1380***b* is inserted into the elongated hole **1380***a***-1**. A nut **1380***b***-2** is screw-engaged with the bolt **1380***b***-1**, whereby the L-shaped hardware **1380***b* is fixed to the L-shaped hardware **1380***a*. Since the bolt **1380***b***-1** is inserted into the elongated hole **1380***a***-1**, a position where the L-shaped hardware **1380***b* is attached to the L-shaped hardware **1380***a* can be adjusted in the horizontal direction. Further, a front edge of the rod-shaped plate section **1380***c* is engaged with the groove section **1376-2***a* of the L-shaped hardware **1376**. As above, the rod-shaped plate section **1380***c* is engaged with the groove of the plate-like section **1376-2**, whereby the slide regulation section **1380** regulates horizontal sliding action of the supporting section **1370**, to thus position the supporting section **1370** in its horizontal direction. As a result of the rod-shaped plate section **1380***c* being engaged with the groove of the plate-like section **1376-2**, the magnet sections **1250** and **1270** and the turning section **1280** are secured in the direction of the arm **1312**.

The slide regulation section **1380** is taken as a part of the constituent elements of the arm **1312**, and the arm **1312** is taken as an arm main body. The arm can also be configured so as to include an arm main body and the slide regulation section **1380**.

Since the sewing machine described in connection with the fourth embodiment is analogous to that described in connection with the third embodiment except the configuration described above, its detailed explanations are omitted here.

In the sewing machine described in connection with the fourth embodiment, the supporting section **1370** is formed so as to be slidable with respect to the slide assist members **1350** and **1352**. Hence, when the supporting section **1370** is placed at the back side of the plate section **1341**, the horizontal position of the supporting section **1370** can be finely adjusted. Thus, the upstream magnet section, the downstream magnet section, and the horizontal position of the turning arm can be finely adjusted. Specifically, after the supporting section **1370** is slid in the horizontal direction to an appropriate position, the rod-shaped plate section **1380***c* is engaged with the L-shaped hardware **1376**. Subsequently, the nut **1380***b***-2** is fastened, thereby fixing the L-shaped hardware **1380***b* to the L-shaped hardware **1380***a*. Incidentally, the rod-shaped plate section **1380***c* may be engaged with the L-shaped hardware **1376** while the nut **1380***b***-2** is loosened with respect to the bolt **1380***b***-1**, and the L-shaped hardware **1380***b* may be moved in the horizontal direction with respect to the L-shaped hardware **1380***a*, whereby the supporting section **1370** is slid with respect to the slide assist members **1350** and **1352**, to thus adjust the position of the supporting section **1370**. Subsequently, the nut **1380***b***-2** can also be fastened.

Operation of the sewing machine described in connection with the fourth embodiment is analogous to that described in connection with the second and third embodiments, and hence its detailed explanation is omitted here.

Fifth Embodiment

A sewing machine of a fifth embodiment is now described. The swing machine of the fifth embodiment is approximately similar to the sewing machine described in connection with the third embodiment in terms of a structure. However, they differ from each other in connection with a structure of the grip section main bodies **1241** and **1261**.

Specifically, as shown in FIG. **39** to FIG. **41**, the grip section main body **1241** of the upstream grip section **1240** has a first plate-like section unit **1400** and a second plate-like section **1408**. The first plate-like section unit **1400** is provided for each of the needle threads. FIG. **39** is a principal cross sectional view in which only the needle thread control mounting section **1340** and the needle thread control section **1230** are fractured. FIG. **39** shows them while omitting needle threads.

The first plate-like section unit **1400** includes a supporting member (an upstream first plate-like section supporting member) **1401** attached to the position of the opening section **1342***a* on the front side of the plate section **1341**; a coiled spring (an upstream coiled spring) **1402** into which a shaft section **1401***c* of the supporting member **1401** is to be inserted; a first plate-like section (an upstream first plate-like section) **1404** into which the shaft section **1401***c* is to be inserted so as to become closer to the back with reference to the coiled spring **1402** along the shaft section **1401***c*; and a protective plate-like section (an upstream protective plate-like section) **1406** fixed to a leading end of the shaft section **1401***c*.

The supporting member **1401** has a square-shaped (rectangular) plate-like section **1401***a*, cylindrical sections **1401***b* projecting from respective four corners of the plate-like section **1401***a* toward the back, and the shaft section (a first shaft section) **1401***c* protruding from a center area on a back surface of the plate-like section **1401***a* toward the back. The upper two cylindrical sections **1401***b* are secured to an upper side of the opening section **1342***a* of the plate section **1341**, and the lower two cylindrical sections **1401***b* are secured to a lower side of the opening section **1342***a* of the plate section **1341**. The length of the cylindrical section **1401***b* and the length of the shaft section **1401***c* are set such that a back surface of the protective plate-like section **1406** contacts a front surface of the second plate-like section **1408**.

The coiled spring **1402** is secured to the shaft section **1401***c* by means of inserting the shaft section **1401***c* into the coiled spring **1402**, thereby forcing the first plate-like section **1404** toward the protective plate-like section **1406**. Driving force of the coiled spring **1402** has such a magnitude that a back surface of the first plate-like section **1404** and a front surface of the protective plate-like section **1406** overlap one another and the back surface of the protective plate-like section **1406** and a front surface of the second plate-like section **1408** overlap one another while the first plate-like section **1404** remains unattracted by the magnet section **1250** and that the needle thread is not fixed by the first plate-like section **1404** and the protective plate-like section **1406**.

The first plate-like section **1404** assumes a circular plate shape, and a hole section **1404***a* into which the shaft section **1401***c* is to be inserted is made in a center of the first plate-like section **1404**. The first plate-like section **1404** is attached to the shaft section **1401***c* by inserting the shaft section **1401***c* to the hole section **1404***a*. The first plate-like section **1404** thereby remains hanging on the plate section **1341** by way of the supporting member **1401**. The first plate-like section **1404** slides in the vertical direction with respect to a front surface of the second plate-like section **1408**, whereby spacing between the first plate-like section **1404** and the protective plate-like section **1406**, the second plate-like section **1408** varies. The diameter of the hole section **1404***a* is formed so as to become smaller than the diameter of the coiled spring **1402**, thereby preventing the coiled spring **1402** from dropping off from the hole section **1404***a* to the back. The first plate-like section **1404** is formed from metal attracted by a magnet, like iron.

The protective plate-like section **1406** is a member for preventing the second plate-like section **1408** from being worn by a needle thread; assumes the shape of a circular plate; and is secured to a leading end of the shaft section **1401***c*. The protective plate-like section **1406** is formed from material unattracted by the magnet (a material to which a magnet does not adhere); that is, a non-magnetic substance. The protective plate-like section **1406** is preferably formed from a nonmagnetic metallic substance (e.g., stainless steel or aluminum).

The second plate-like section **1408** is formed into the shape of a plate having an approximately-C-shaped cross sectional profile and from a synthetic resin film. The second plate-like section **1408** is fitted into a cutout formed on the front side of and along upper and lower sides of the opening section **1342***a*. Specifically, the second plate-like section **1408** includes a second plate-like section main body section Pt-**1** assuming a shape of an elongated rectangular plate; a projecting section Pt-**2** assuming a shape of an elongated rectangular plate that continually extends toward the back from an upper side which is one longitudinal side of the second plate-like section main body section Pt-**1**; and a projecting section Pt-**3** assuming a shape of an elongated rectangular plate that continually extends toward the back from a lower side which is the other longitudinal side of the second plate-like section main body section Pt-**1**. The second plate-like section main body section pt-**1** grips the needle thread along with the first plate-like section **1404**.

The needle thread **3** is situated between the first plate-like section **1404** and the protective plate-like section **1406**. As shown in FIG. **41**, the needle thread J is arranged diagonally over the plate-like section **1401***a* so as not to contact the shaft section **1401***c* and the coiled spring **1402** (i.e., along a direction from an upper left position on the plate-like section **1401***a* to a lower right position on the same when viewed from the front).

The grip section main body **1241** is configured in the manner as above, the first plate-like section **1404** and the protective plate-like section **1406** are driven toward the second plate-like section **1408** by means of the coiled spring **1402**. Even when the magnet section **1205** does not attract the first plate-like section **1404**, the first plate-like section **1404** contacts the protective plate-like section **1406**, and the protective plate-like section **1406** remains in contact with the second plate-like section **1408**. Accordingly, vibration sound, which would otherwise occur as a result of repeated opening/closing of the grip section main body **1241**, or vibration sound, which would otherwise be caused by vibrations of a head, can be prevented. Specifically, in the case of the second to fourth embodiments, the first plate-like section stays in a mere hanging state. Therefore, when the first plate-like section is attracted by the magnet section, the first plate-like section contacts the second plate-like section, thereby generating sound. Further, the first plate-like section repeatedly contacts the second plate-like section as a result of repeated opening/closing of the grip section main body, thereby generating sound. The first plate-like section contacts the second plate-like section by means of vibration of a head, thereby generating sound. In the present embodiment, occurrence of such vibration sound can be prevented. Specifically, during actual embroidering, the first plate-like section **1404** and the protective plate-like section **1406** are driven toward the second plate-like section **1408** by means of the coiled spring **1402** in the first plate-like section units **1400** corresponding to unselected needle bars as well as in the first plate-like section unit **1400** corresponding to the selected needle bar. Hence, vibration sound, which would otherwise be caused by repeated opening/closing of the grip section main body **1241**, and vibration sound, which would otherwise be caused by vibration of a head, are prevented. Since the protective plate-like section **1406** is interposed between the second plate-like section **1408** and the needle thread, abrasion of the second plate-like section **1408**, which would otherwise be caused when the needle thread contacts the second plate-like section **1408**, can be prevented. Specifically, in the case of the second to fourth embodiments, the needle thread remains in contact with the second plate-like section. Therefore, when the second plate-like section is made of a synthetic resin film, the second plate-like section may be worn by friction with the needle thread as a result of the needle thread moving along a path. However, abrasion of the second plate-like section **1408** can be prevented by providing the protective plate-like section **1406**. Further, as a result of the protective plate-like section **1406** is made of metal, abrasion of the protective plate-like section **1406** itself can be prevented.

The grip section main body **1261** of the downstream grip section **1260** is structurally same to the grip section main body **1241**. As shown in FIGS. **39** to **41**, the grip section main body **1261** has a first plate-like section units **1410** and a second plate-like section **1418**. The first plate-like section unit **1410** is provided for each of the needle threads.

The first plate-like section unit **1410** includes a supporting member (a downstream first plate-like section supporting member) **1411** attached to a position of the opening section **1342***c* on the front surface of the plate section **1341**; a coiled spring (a downstream coiled spring) **1412** inserted into a shaft section **1411***c* of the supporting member **1411**, a first plate-like section (a downstream first plate-like section) **1414** that is inserted into the shaft section **1411***c* and that is provided at a position on the shaft section **1411***c* closer to the back side with reference to the coiled spring **1412**, and a protective plate-like section (a downstream protective plate-like section) **1416** fixed to a leading end of the shaft section **1411**.

The supporting member **1411** is structurally identical with the supporting member **1401** and includes a plate-like section **1411***a*, cylindrical sections **1411***b*, and the shaft section (a second shaft section) **1411***c*. The plate-like section **1411***a* is structurally identical with the plate-like section **1401***a*, the cylindrical section **1411***b* is structurally identical with the cylindrical section **1401***b*, and the shaft section **1411***c* is structurally identical with the shaft section **1401***c*, and hence their detailed explanations are omitted here. The upper two cylindrical sections **1411***b* are secured to a position on the plate section **1341** above the opening section **1342***c*. The lower two cylindrical sections **1411***b* are secured to a position on the plate section **1341** below the opening section **1342***c*.

The coiled spring **1412** is identical with the coiled spring **1402** in terms of a configuration, and the protective plate-like section **1416** is structurally identical with the protective plate-like section **1406**, and hence their detailed explanations are omitted here.

The first plate-like section **1414** is structurally identical with the first plate-like section **1404**, and the second plate-like section **1418** is structurally identical with the second plate-like section **1408**, and hence their detailed explanations are omitted here. A hole section **1414***a* into which the shaft section **1411***c* is inserted is made in the first plate-like section **1414**.

Like the grip section main body **1241**, the grip section main body **1261** is configured as mentioned above, whereby the first plate-like section **1414** and the protective plate-like section **1416** are driven toward the second plate-like section **1418** by means of the coiled spring **1412**. Accordingly, it is possible to prevent occurrence of vibration sound, which would otherwise be caused by repeated opening/closing of the grip section main body **1261**.

Like the grip section main body **1241**, the protective plate-like section **1416** is interposed between the second plate-like section **1418** and the needle thread. Hence, abrasion of the second plate-like section **1418**, which would otherwise be caused when the needle thread contacts the second plate-like section **1418**, can be prevented.

Since the sewing machine described in connection with the fifth embodiment is analogous to that described in connection with the third embodiment except the configuration described above, its detailed explanations are omitted here. In the above descriptions, the sewing machine of the fifth embodiment has been described on condition that the configuration described in connection with the fifth embodiment is taken as the configuration of the grip section main bodies **1241** and **1261** described in connection with the sewing machine of the third embodiment. However, the configuration described in connection with the fifth embodiment can also be adopted for the configuration of the grip section main bodies **1241** and **1261** described in connection with the sewing machine of the fourth embodiment.

Sixth Embodiment

A sewing machine of a sixth embodiment is now described. In terms of a configuration, the sewing machine described in connection with the sixth embodiment is approximately analogous to the sewing machine described in connection with the third embodiment. However, they differ from each other in relation to the configuration of the grip section main bodies **1241** and **1261**. Further, they differ from each other in that the plate-like section **1360***e* in the supporting section **1360** is provided with projecting members **1362** and **1364** for pressing sliding members **1421** and **1431** toward the front.

Specifically, as shown in FIG. **42** to FIG. **45**, the grip section main body **1241** of the upstream grip section **1240** has first plate-like section units **1420** and a second plate-like section **1426**. The first plate-like section units **1420** are provided for respective needle threads. FIG. **92** is a principal cross sectional view in which only the needle thread control mounting section **1340** and the needle thread control section **1230** remain fractured. FIG. **42** shows them while omitting needle threads.

The first plate-like section unit **1420** includes the sliding member (an upstream sliding member) **1421**; a first plate-like section **1422** into which the sliding member **1421** is to be inserted; and a coiled spring (an upstream driving member) **1424** into which the sliding member **1421** is to be inserted and that is provided at a position on the sliding member **1421** closer to the back side with reference to the first plate-like section **1422**.

The sliding member **1421** has a sliding member main body **1421***a* and a retaining section **1421***b* secured to a back-side end of the sliding member **1421**. The sliding member main body **1421***a* has a linear rod-shaped shaft section **1421***a*-**1** and a retaining section **1421***a*-**2** placed at a front end of the shaft section **1421***a*-**1**. The entirety of the sliding member main body **1421***a* is formed into an integrated fashion. Both the retaining section **1421***b* and the retaining section **1421***a*-**2** assume the shape of a circular plate and an approximately identical diameter. A circular hole section **1342***f* into which the shaft section **1421***a*-**1** is to be inserted is formed for each needle bar at a position on the plate section **1341** above the opening section **1342***a*. The sliding member **1421** is supported by the hole section **1342***f* so as to be slidable along an axis direction of the sliding member **1421** (i.e., a front-back direction of a head).

The first plate-like section (an upstream first plate-like section) **1422** assumes the shape of a rectangular plate. A hole section **1422***a* into which the shaft section **1421***a*-**1** is to be inserted is formed at an upper position on the first plate-like section **1422**. The diameter of the hole section **1422***a* is made smaller than the diameter of the retaining sections **1421***b* and **1421***a*-**2**. The first plate-like section **1422** is made of metal attracted by a magnet, like iron. The first plate-like section **1422** is attached to the shaft section **1421***a*-**1** by inserting the shaft section **1421***a*-**1** into the hole section **1422***a*. As a result, the first plate-like section **1422** stays hanging on the plate section **1341** by way of the sliding member **1421** and is formed so as to be slidable in the front-back direction along the direction of an axis line of the shaft section **1421***a*-**1**. The first plate-like section **1422** is slidable in a vertical direction with respect to a front surface of the second plate-like section **1426**, whereby spacing between the first plate-like section **1422** and the second plate-like section **1426** becomes variable.

The coiled spring **1424** is attached to the shaft section **1421***a*-**1** by inserting the shaft section **1421***a*-**1** to the coiled spring **1424** and drives the retaining section **1421***b* to the back. When the retaining section **1421***b* is not pressed to the front by the projecting member **1362**, the first plate-like section **1422** comes into contact with the second plate-like section **1426**. When the sliding member **1421** is not pressed by the projecting member **1362** (a state shown in FIG. **44**(*a*)), the driving force of the coiled spring **1424** is such a level that the back surface of the first plate-like section **1422** contacts and overlaps the front surface of the second plate-like section **1426**. In a state shown in FIG. **44**(*a*), the first plate-like section **1422** is pressed toward the second plate-like section **1426**, and the first plate-like section **1422** cannot slide in the front-back direction.

The second plate-like section **1426** is structurally analogous to the second plate-like section **1408** of the fifth embodiment and formed from a synthetic resin film into the shape of a plate having an approximately-C-shaped cross sectional profile. The second plate-like section **1426** is fitted into a cutout formed on the front side of and along upper and lower sides of the opening section **1342***a*.

The projecting member (an upstream press operation member) **1362** fixedly stands upright on a front surface of the plate-like section **1360***e* of the supporting section **1360** and at a center of the magnet section **1250** along its horizontal direction. The projecting member **1362** assumes approximately a shaft shape, and a diameter of its leading end is made large. Specifically, the projecting member **1362** has a shaft section **1362***a* and a head section **1362***b* that is placed at a leading end of the shaft section and that has a diameter (a maximum diameter) larger than the diameter of the shaft section. A front side of the head section **1362***b* is formed into an approximately hemispherical shape so that the sliding member **1421** is easily pressed to the front. Specifically, a front-side leading end of the head section **1362***b* assumes a spherical shape. An axial length ha-**1** of the projecting member **1362** is made longer than a length ha-**2** between the sliding member **1421** and the plate-like section **1360***e* achieved when the sliding member **1421** is not pressed by the projecting member **1362**. When the magnet section **1250** comes to a position on the back side of the first plate-like section **1422** corresponding to the selected needle bar, the projecting member **1362** presses the retaining section **1421***b* of the sliding member **1421** to the front, whereupon the first plate-like section **1422** becomes slidable in the front-back direction.

In the configuration of the sixth embodiment, the magnet section **1250** does not exist on the back side of the first plate-like section **1422** as shown in FIG. **44**(*a*) in connection with the first plate-like sections **1422** corresponding to needle bars other than the selected needle bar. Since the projecting member **1362** does not press the sliding member **1421**, the first plate-like section **1422** is pressed toward the second plate-like section **1426** and cannot slide in its front-back direction.

In the meantime, in connection with the first plate-like section **1422** corresponding to the selected needle bar (namely, the upstream first plate-like section that is an objective of attraction), the magnet section **1250** exists on the back side of the first plate-like section **1422** as shown in FIG. **44**(*b*). The projecting member **1362** presses the retaining section **1421***b* of the sliding member **1421** to the front, so that the first plate-like section **1422** becomes slidable in the front-back direction. Hence, the first plate-like section **1422** and the second plate-like section **1426** grips the needle thread as a result of the magnet section **1250** attracting the first plate-like section **1422**, thereby fixing the needle thread. Further, when the magnet section **1250** does not attract the first plate-like section **1422**, the first plate-like section **1422** is not pressed back by the sliding member **1421**, so that the needle thread is released from a gripped state.

As a result of adoption of the foregoing configuration, in connection with the first plate-like sections **1422** corresponding to the needle bars except the selected needle bar, the first plate-like sections **1422** are pressed toward the second plate-like section **1426**. Hence, sound, which would otherwise be generated when the first plate-like section **1422** contacting the second plate-like section **1426**, does not occur, and vibration sound will not also be caused by vibration of a head. Further, the first plate-like section **1422** corresponding to the selected needle bar is not pressed to the back by the sliding member **1421**. Hence, the needle thread can be sufficiently released from the gripped state.

In the case of the fifth embodiment, the first plate-like section **1404** (**1414**) is driven toward the protective plate-like section **1406** (**1416**) at all times. Hence, even when the first plate-like section is unattracted by the magnet section, the needle thread may not be sufficiently released. However, in the present embodiment, when the magnet section does not attract the first plate-like section, the needle thread can be sufficiently released.

As shown in FIGS. **42** to **45**, the grip section main body **1261** of the downstream grip section **1260** has a first plate-like section unit **1430** and a second plate-like section **1436**. The first plate-like section unit **1430** is provided for each of needle threads.

Since the first plate-like section unit **1430** is structurally analogous to the first plate-like section unit **1420** and has the sliding member (a downstream sliding member) **1431**, a first plate-like section **1432** inserted into the sliding member **1431**, and a coiled spring (a downstream driving member) **1434** into which the sliding member **1431** is to be inserted and that is provided at a position on the sliding member **1431** closer to the back side with reference to the first plate-like section **1432**.

The sliding member **1431** is structurally similar to the sliding member **1421**. The sliding member **1431** has a sliding member main body **1431***a* and a retaining section **1431***b* fixed to an end on the back side of the sliding member **1431**. The sliding member main body **1431***a* has a linear rod-shaped shaft section **1431***a*-**1** and a retaining section **1431***a*-**2** provided at an end on the front side of the shaft section **1431***a*-**1**. The entirety of the sliding member main body **1431***a* is integrally formed. A circular hole section **1342***g* into which the shaft section **1431***a*-**1** is to be inserted is formed at a position on the plate section **1341** above the opening section **1342***c* for each needle bar. The sliding member **1431** is slidably supported by the hole section **1342***g*.

The first plate-like section (a downstream first plate-like section) **1432** is structurally analogous to the plate-like section **1422**. A hole section **1432***a* into which the shaft section **1431***a*-**1** is to be inserted is formed in the first plate-like section **1432**.

The coiled spring **1434** has the same structure as that of the coiled spring **1424**. The second plate-like section **1436** has the same structure as that of the second plate-like section **1418** described in connection with the fifth embodiment.

The projecting member (a downstream press operation member) **1364** fixedly stands upright on the front surface of the plate-like section **1360***e* of the supporting section **1360** and at a center of the magnet section **1270** along its horizontal direction. The projecting member **1364** has the same structure as that of the projecting member **1362**. When the magnet section **1270** comes to a position on the back side of the first plate-like section **1432** corresponding to the selected needle bar (i.e., the downstream first plate-like section that is an object of attraction), the projecting member **1364** presses the retaining section **1431***b* of the sliding member **1431** to the front, whereupon the first plate-like section **1432** becomes slidable in the front-back direction.

As a result of adoption of the above configuration, the first plate-like sections **1432** corresponding to needle bars other than the selected needle bar are pressed toward the second plate-like section **1436**, in the same way as described in the case of the grip section main body **1241**. Sound, which would otherwise be caused when the first plate-like section **1432** contacts the second plate-like section **1436**, does not occur, and vibration sound will not also be caused by vibration of a head. The first plate-like section **1432** corresponding to the selected needle bar is not pressed to the back by the sliding member **1431**, so that the needle thread can be sufficiently released from the pinched and gripped state.

The configuration of the sixth embodiment is analogous to that of the third embodiment except the foregoing configuration, and hence its detailed explanation is omitted. In the descriptions, the sewing machine of the third embodiment has been explained as employing the configuration of the sixth embodiment in connection with the configuration of the grip section main bodies **1241** and **1261**. Further, the sewing machine of the fourth embodiment has been explained as employing the configuration of the sixth embodiment in connection with the sliding members **1421** and **1431**. However, the sewing machine of the fourth embodiment can additionally include the configuration of the grip section main bodies **1241** and **1261** in connection with the configuration of the sixth embodiment and further include the sliding members **1421** and **1431**.

In the second to sixth embodiments, the needle bar case main body **1330** can also be given the name "needle bar case."

In the drawing, direction Y1-Y2 is perpendicular to X1-X2 direction, and Z1-Z2 direction is perpendicular to X1-X2 direction and Y1-Y2 direction.

DESCRIPTIONS OF THE REFERENCE NUMERALS AND SYMBOLS

5, **205**, **1205** SEWING MACHINE
7, **207**, **1207** HEAD

10 MACHINE ELEMENT GROUP
12*a*, **12***a***-1**, **12***a***-2**, **12***a***-3**, **12***a***-4**, **12***a***-5**, **12***a***-6**, **12***a***-7**, **12***a***-8**, **12***a***-9** THREAD TAKE-UP LEVER
12*b*, **12***b***-1**, **12***b***-2**, **12***b***-3**, **12***b***-4**, **12***b***-5**, **12***b***-6**, **12***b***-7**, **12***b***-8**, **12***b***-9** NEEDLE BAR
12*ba* SEWING NEEDLE
12*bb* PIN HOLE
12*c* SHUTTLE
12*d* SEWING FRAME
14*a* NEEDLE BAR CONNECTING STUD
14*b* NEEDLE BAR ACTUATION MEMBER
14*c* BASE NEEDLE BAR
20 MAIN SPINDLE MOTOR
21, **87** ENCODER
22 MAIN SPINDLE
24 FRAME ACTUATOR
30, **230**, **1230** NEEDLE THREAD CONTROL SECTION
40, **240**, **1240** UPSTREAM GRIP SECTION
41, **61**, **241**, **261**, **1241**, **1261** GRIP SECTION MAIN BODY
50, **70** SOLENOID
60, **260**, **1260** DOWNSTREAM GRIP SECTION
80, **280**, **1280** TURNING SECTION
81, **281**, **1281** TURNING ARM
82, **282**, **1282** MAIN BODY SECTION
84 TUBULAR PORTION
86, **286**, **1286** NEEDLE THREAD MOTOR
90 CONTROL CIRCUIT
92 MEMORY DEVICE
110, **310**, **1310** CASE
120, **320** FRAME
242-1, **242-2**, **242-3**, **242-4**, **242-5**, **242-6**, **262-1**, **262-2**, **262-3**, **262-4**, **262-5**, **262-6**, **1242-1**, **1242-2**, **1242-3**, **1242-4**, **1242-5**, **1242-6**, **1242-7**, **1242-8**, **1242-9**, **1262-1**, **1262-2**, **1262-3**, **1262-4**, **1262-5**, **1262-6**, **1262-7**, **1262-8**, **1262-9**, **1404**, **1414**, **1422**, **1432** FIRST PLATE-LIKE SECTION
244, **264**, **1244**, **1264**, **1408**, **1418**, **1426**, **1436** SECOND PLATE-LIKE SECTION
246, **266** MOUNTING MEMBER
250, **270**, **1250**, **1270** MAGNET SECTION
252, **254**, **272**, **274**, **1252**, **1254**, **1272**, **1274**, **1290**, **1336** GUIDE MEMBER
284, **1284** HOOK SECTION
284*a* GROOVE SECTION
288, **1288** NEEDLE THREAD SUPPORTING MEMBER
288*a*, **288***b*, **1288***a*, **1288***b* CIRCULAR-ARC MEMBER
288*c*, **1288***c* CONNECTING MEMBER
290 GUIDE MEMBER
292, **1337** TENSION SPRING
300, **302** NEEDLE THREAD GUIDE
312, **1312** ARM
314, **1314** NEEDLE BAR CASE
314*a* FRONT SECTION
110*a*, **110***b*, **316***a*, **316***b*, **316***c*, **316***d*, **1342***a*, **1342***b*, **1342***c* OPENING SECTION
1330 NEEDLE BAR CASE MAIN BODY
1340 NEEDLE THREAD CONTROL MOUNTING SECTION
1341 PLATE SECTION
1350, **1352** SLIDE ASSIST MEMBER
1335, **1360**, **1370** SUPPORTING SECTION
1362, **1364** PROJECTING MEMBER
1380 SLIDE REGULATION SECTION
1400, **1410**, **1420**, **1430** FIRST PLATE-LIKE SECTION UNIT
1401, **1411** SUPPORTING MEMBER
1401*a*, **1411***a* PLATE-LIKE SECTION
1401*b*, **1411***b* CYLINDRICAL SECTION
1401*c*, **1411***c* SHAFT SECTION
1402, **1412**, **1424**, **1434** COILED SPRING
1404*a*, **1414***a* HOLE SECTION
1406, **1416** PROTECTIVE PLATE-LIKE SECTION
1421, **1431** SLIDING MEMBER

The invention claimed is:

1. A sewing machine comprising:

a thread take-up lever formed in a swayable manner;

a needle thread control section that is disposed at an upstream position on a needle thread path of the thread take-up lever and that includes

an upstream grip section which includes an upstream grip section main body for pinching to thereby grip a needle thread and an upstream actuation section for switching, with respect to the upstream grip section main body, between a closed state in which the needle thread is gripped and an open state in which a needle thread is released from a gripped state,

a downstream grip section which is disposed at a downstream position on a needle thread path of the upstream grip section and which includes a downstream grip section main body for pinching to thereby grip a needle thread and a downstream actuation section for switching, with respect to the downstream grip section main body, between a closed state in which the needle thread is gripped and an open state in which the needle thread is released from a gripped state, and

a turning section which turns the needle thread existing between the upstream grip section main body and the downstream grip section main body and which has a turning arm to contact the needle thread and a needle thread motor to turn the turning arm; and

a control section, in a control zone for each stitch, that—in a torque control zone including at least a portion of a zone from a bottom dead point to a top dead point of the thread take-up lever during which the thread take-up lever draws the needle thread with respect to processed fabric to be sewn with the needle thread—controls the needle thread motor in accordance with a torque value in such a way that tension is imparted to the needle thread against a direction in which the thread take-up lever draws the needle thread while the upstream grip section main body is closed and while the downstream grip section main body is opened, to thus impart rotating force to the turning arm, and

that—in a position control zone which is at least a portion of a zone other than the torque control zone achieved while the upstream grip section main body is opened and while the downstream grip section main body is closed—controls the needle thread motor in accordance with angle position data pertaining to the needle thread motor in such a way that an angle of the needle thread motor returns to an initial angle position of the needle thread motor which is a rotational position of the needle thread motor, thereby imparting rotating force to the turning arm to thus draw the needle thread from an upstream position.

2. The sewing machine according to claim **1**, further comprising:

an arm making up an enclosure of the sewing machine;

a needle bar case that is provided so as to be slidable in a horizontal direction with respect to the arm and that includes first opening sections made at positions between the upstream grip section main body and the downstream grip section main body in a vertical direction such that a leading end of the turning arm of a turning section can be exposed to the front side, a second opening section which is provided above the first opening section and on which the upstream magnet section fronts, and a third opening section which is provided below the first opening section and on which a downstream magnet section fronts;

a plurality of needle bars provided in the needle bar case; and

needle thread supporting members that each is provided in the needle bar case and that each supports the needle thread in its horizontal direction at the position of the first opening section, wherein

the thread take-up lever is placed while being exposed from a position in the needle bar case below the downstream grip section to a front;

the turning arm is turned while remaining in contact with the needle thread supported by the needle thread supporting member, thereby turning the needle thread;

the upstream grip section main body is placed on a front side of the needle bar case and, and has a plurality of upstream first plate-like sections which is formed into a shape of a plate from a magnetic substance; that is, a material attracted by the magnet and which is provided in the needle bar case and an upstream second plate-like section which is provided at back side of the upstream first plate-like sections and on a front side of the second opening section and which is formed into a shape of a plate from a non-magnetic substance unattracted by the magnet;

the upstream actuation section is a magnet section serving as the upstream magnet section and secured to the arm-side at a back side of the upstream second plate-like section and switches between a closed state in which the upstream first plate-like section is attracted by magnetic force, to thus pinch and grip the needle thread between the upstream first plate-like section and the upstream second plate-like section and an open state in which attraction caused by the magnetic force is released to thereby release the needle thread from the gripped state;

the downstream grip section main body is placed on a front side of the needle bar case and below the upstream grip section main body and has a plurality of downstream first plate-like sections which are formed from a magnetic substance which is attracted by the magnet into a shape of a plate and which are provided in the needle bar case and a downstream second plate-like section which is provided at back side of the downstream first plate-like sections and on a front side of the second opening section and which is formed into a shape of a plate from a non-magnetic substance unattracted by the magnet; and

the downstream actuation section is a magnet section serving as the downstream magnet section and secured to the arm-side at a back side of the downstream second plate-like section and switches between a closed state in which the downstream first plate-like section is attracted by magnetic force, to thus pinch to thereby grip the needle thread between the downstream first plate-like section and the downstream second plate-like section and an open state in which the needle thread is released from the gripped state by means of canceling attraction caused by the magnetic force.

3. The sewing machine according to claim **2**, wherein the needle thread is guided downward after passing through spacing between the upstream first plate-like section and the upstream second plate-like section of the upstream grip section main body, reaches the needle thread supporting member while a path of the needle thread is inverted by a first needle thread path inverting member provided on the needle bar case, is guided downwardly from the needle thread supporting member and subsequently passes through spacing between the downstream first plate-like section and the downstream second plate-like section in the downstream grip section main body, reaches the thread take-up lever while a path of the needle thread is inverted by a second needle thread path inverting member provided in the needle bar case, and reaches the sewing needle attached to the needle bar while being guided downward from the thread take-up lever.

4. The sewing machine according to claim **3**, wherein the first needle thread path inverting member has a main body section having a cylindrical peripheral and a base end section which continually extends from a base end of the main body section and which is formed so as to have a diameter smaller than a diameter of the main body section; an indentation section used for inserting an end section of the base-end section side of the main body section and a hole section which continually extends from the indentation section and which is used for inserting the base end section are formed at positions on the needle bar case where the first needle thread path inverting member and the second needle thread path inverting member are to be attached; the base end section is inserted into the hole section; and an end section of the base-end section side of the main body section is inserted into the indentation section.

5. The sewing machine according to claim **2**, wherein first guide members set above and below the upstream first plate-like section on the needle bar case are placed at positions that differ from each other in a horizontal direction in the upstream grip section main body; each of the needle thread paths existing between the upstream first plate-like section and the upstream second plate-like section is formed obliquely with respect to a vertical direction; second guide members set above and below the downstream first plate-like section on the needle bar case are placed at positions that differ from each other in a horizontal direction in the downstream grip section main body; and each of the needle thread paths existing between the downstream first plate-like section and the downstream second plate-like section is formed obliquely with respect to a vertical direction.

6. The sewing machine according to claim **5**, wherein each of the first guide members and the second guide members has a main body section having a cylindrical peripheral and a base end section which continually extends from a base end of the main body section and which is formed so as to have a diameter smaller than a diameter of the main body section; an indentation section used for inserting an end section on the base-end section side of the main body section and a hole section which continually extends from the indentation section and which is used for inserting the base end section are formed at positions on the needle bar case where the first guide members and the second guide members are to be attached; the base end section is inserted into the hole section; and an end section on the base-end section side of the main body section is inserted into the indentation section.

7. The sewing machine according to claim **2**, wherein the needle bar case has a needle bar case main body that is provided with the thread take-up levers and the needle bars and that is provided so as to be slidable with respect to the arm and a plate-like plate section provided on an upper surface of the needle bar case main body; and the plate section has the first opening section, the second opening section, the third opening section, the upstream grip section, the downstream grip section, and the needle thread supporting member.

8. The sewing machine according to claim **2**, wherein a magnet section/motor supporting member that supports the upstream magnet section, the downstream magnet section, the needle thread motor is secured to the arm.

9. The sewing machine according to claim **2**, further comprising a magnet section/motor supporting member that supports the upstream magnet section, the downstream magnet section, and the needle thread motor, a sliding support member that is provided in the needle bar case and that slidably supports the magnet section/motor supporting member in a horizontal direction and a slide regulation member that is secured to the arm and that regulates horizontal sliding action of the magnet section/motor supporting member to horizontally position the magnet section/motor supporting member, wherein horizontal sliding action of the magnet section/motor supporting member is regulated by the slide regulation member, whereby the upstream magnet section, the downstream magnet section, and the needle thread motor are fixedly placed on the arm side.

10. The sewing machine according to claim **2**, further comprising an upstream first plate-like section supporting members that each has a first shaft section to be inserted into a hole section of the upstream first plate-like section and that is provided on a front side of the needle bar case, an upstream coiled springs into each of which the first shaft section is to be inserted, and an upstream protective plate-like sections that each is secured to a leading end of the first shaft section and that is formed from a non-magnetic substance unattracted by the magnet, wherein

the upstream first plate-like section is provided with the hole section used for inserting the first shaft section; the upstream second plate-like section remains in contact with a surface of the upstream protective plate-like section that is on the other side with respect to the upstream first plate-like section; the upstream first plate-like section is provided between the upstream coiled spring and the upstream protective plate-like section while the first shaft section remains inserted into the hole section; and the upstream first plate-like section is driven toward the upstream protective plate-like section by means of the upstream coiled spring; and

further comprising a downstream first plate-like section supporting members that each has a second shaft section to be inserted into a hole section of the downstream first plate-like section and that is provided on a front side of the needle bar case, a downstream coiled springs into which the second shaft section is to be inserted, and a downstream protective plate-like sections that each is secured to a leading end of the second shaft section and that is formed from a non-magnetic substance unattracted by the magnet, wherein

the downstream first plate-like section is provided with the hole section used for inserting the second shaft section; the downstream second plate-like section remains in contact with a surface of the downstream protective plate-like section that is on the other side with respect to the downstream first plate-like section; the downstream first plate-like section is provided between the downstream coiled spring and the downstream protective plate-like section while the second shaft section remains inserted into the hole section; and the downstream first plate-like section is driven toward the downstream protective plate-like section by means of the downstream coiled spring.

11. The sewing machine according to claim **2**, further comprising an upstream sliding members that each is inserted into a position above the second opening section on the needle bar case and that each is provided so as to be slidable along a direction of an axis line of the upstream sliding member and an upstream driving members that each drives the upstream sliding member to a back side of the needle bar case, wherein the upstream first plate-like section is provided while hanging on the upstream sliding member, and an upstream press operation member for pressing the upstream sliding member corresponding to the upstream first plate-like section which is attracted by the upstream magnet section in a direction opposite to a driving direction of the upstream driving member is provided on the arm side; and

further comprising a downstream sliding members that each is inserted into a position above the third opening section on the needle bar case and that each is provided for each of the upstream first plate-like sections so as to be slidable in an axial direction of the downstream sliding member and a downstream driving members that each drives the downstream sliding member to the back side of the needle bar case, wherein the downstream first plate-like section is provided while hanging on the downstream sliding member, and a downstream press operation member for pressing the downstream sliding member corresponding to the downstream first plate-like section which is attracted by the downstream magnet section in a direction opposite to a driving direction of the downstream driving member is provided on the arm side.

12. The sewing machine according to claim **2**, wherein the needle thread supporting member supports a needle thread on the front side of the first opening section.

13. The sewing machine according to claim **1**, wherein the control section performs control operation in accordance with torque data whose torque value is specified for each stitch in the torque control zone and detects, at a starting point of the position control zone, a current angle position of the needle thread motor in the position control zone, generates angle correspondence data which specify an angle of the needle thread motor from the current angle position to an initial angle position of the needle thread motor for each angle of a main spindle motor representing a rotational position of the main spindle motor which rotates a main spindle for transmitting power to the thread take-up lever, and controls a position of the needle thread motor to its angle of the needle thread motor corresponding to the angle of the main spindle motor as the angle of the main spindle motor changes as a result of rotation of the main spindle motor.

14. The sewing machine according to claim **13**, wherein, during torque control performed in the torque control zone, a value of a torque deviation is calculated from a torque value in the torque data and a torque value based on a current value fed to the needle thread motor, and an electric current is fed to the needle thread motor in accordance with the calculated torque deviation.

15. The sewing machine according to claim **13**, further comprising a motor angle detection section for detecting a rotational position of the needle thread motor, wherein position control is performed during position control performed in the position control zone along operation control steps including:

a reading step of reading an angle of the needle thread motor from the angle correspondence data,

a speed data calculation step of calculating an amount of change per unit time in angle data read in the reading step, to thus calculate speed data, a torque data calculation step of detecting an amount of change per unit time in the speed data calculated in the speed data calculation step, to thus calculate torque data; a location deviation calculation step of calculating a value of a location deviation from the angle data read in the reading step and the motor angle data read by the motor angle detecting section,

a speed deviation calculation step of calculating a value of a speed deviation from the calculated value of the location deviation, the calculated speed data, and the amount of change per unit time in motor angle detected by the angle detection section,

a torque deviation calculation step of calculating a value of a torque deviation from the calculated value of the speed deviation, the calculated torque data, and a value of torque based on a current value fed to the motor, and

a current feeding step of feeding an electric current to the motor in accordance with the calculated value of the toque deviation.

16. A sewing machine comprising:

an arm making up an enclosure of the sewing machine;

a needle bar case that is provided so as to be slidable in a horizontal direction with respect to the arm and that includes first opening sections made at positions between an upstream grip section main body and a downstream grip section main body in a vertical direction such that a leading end of a turning arm of a turning section can be exposed to the front side, a second opening section which is provided above the first opening section and on which an upstream magnet section fronts, and a third opening section which is provided below the first opening section and on which a downstream magnet section fronts;

a plurality of thread take-up levers that are provided on a front side of the needle bar case in an exposed fashion and that are provided at downstream positions on needle thread paths with respect to a downstream grip section in a swayable manner;

a plurality of needle bars provided in the needle bar case;

an upstream grip section that has

an upstream grip section main body that is placed on a front side of the needle bar case, that pinches to thereby grip the needle thread, and that has upstream first plate-like sections which is formed from a magnetic substance that is a material attracted by the magnet, and which is provided for the respective needle bars and an upstream second plate-like section which is provided at back side of the upstream first plate-like sections and on a front side of the second opening section and which is formed from a non-magnetic substance unattracted by the magnet, and

an upstream magnet section that is secured to the arm side and that switches between a closed state in which the needle thread is pinched to thereby grip between the upstream first plate-like section and the upstream second plate-like section by means of attracting the upstream first plate-like section from a back side of the upstream second plate-like section by means of magnetic force and an open state in which the needle thread is released from the gripped state by canceling attraction caused by magnetic force;

the downstream grip section that is placed at a downstream position along a needle thread path of the upstream grip section and that has

the downstream grip section main body which is placed on a front surface side of the needle bar case and below the upstream grip section main body, which pinches to thereby grip the needle thread, and which has a downstream first plate-like sections which is formed from a magnetic substance that is a material attracted by a magnet and which is provided for each of the needle bars and a downstream second plate-like section that is provided at back side of the downstream first plate-like sections and on a front side of the second opening section and that is formed from a non-magnetic substance unattracted by the magnet, and

a downstream magnet section that is secured to the arm side and that switches between a closed state in which the needle thread is pinched to thereby grip between the downstream first plate-like section and the downstream second plate-like section by means of attracting the downstream first plate-like section from a back side of the downstream second plate-like section by magnetic force and an open state in which the needle thread is released from a gripped state by canceling attraction caused by the magnetic force;

needle thread supporting members that each is provided in the needle bar case and that each supports the needle thread in its horizontal direction at the position of the first opening section;

a turning section that turns the needle thread existing between the upstream grip section main body and the downstream grip section main body and that has the turning arm which contacts the needle thread supported by the needle thread supporting member and a needle thread motor which is secured to the arm side and which turns the turning arm; and

a control section, in a control zone for each stitch, that—in a torque control zone including at least a portion of a zone from a bottom dead point to a top dead point of the thread take-up lever during which the thread take-up lever draws the needle thread with respect to processed fabric to be sewn with the needle thread—controls the needle thread motor in accordance with a torque value in such a way that tension is imparted to the needle thread against a direction in which the thread take-up lever draws the needle thread in accordance with torque data which are generated from embroidery data and whose torque value is specified for each stitch, while the upstream grip section main body is closed and while the downstream grip section main body is opened, thereby imparting rotating force to the turning arm in an upward direction and

that—in a position control zone which is at least a portion of a zone other than the torque control zone achieved while the upstream grip section main body is opened and while the downstream grip section main body is closed detects at a starting point of the position control zone a current angle position of the needle thread motor which is a rotational position of the needle thread motor, generates angle correspondence data which specify an angle of the needle thread motor from the current angle position to an initial angle position of the needle thread motor for each angle of a main spindle motor representing a rotational position of the main spindle motor which rotates a main spindle for transmitting power to the thread take-up levers and the needle bars, controls a position of the needle thread motor to its angle of the needle thread motor corresponding to the angle of the main spindle motor as the angle of the main spindle motor changes as a result of rotation of the main spindle motor in such a way that the angle of the needle thread motor returns to an initial angle position of the needle thread motor, to thus impart rotating force to the turning arm in an upward direction and draw a needle thread from an upstream position, turns the turning arm downward so as to recede to a receded position and slide the needle bar case when processing proceeds to control of a next stitch and when a needle thread to be selected is changed, thereby letting the upstream magnet section, the downstream magnet section, and the turning arm come to a position of the selected needle thread.

17. A sewing machine comprising:

an arm making up an enclosure of the sewing machine;

a needle bar housing case that is disposed so as to be slidable in a horizontal direction with respect to the arm and that houses a plurality of needle bars;

a tabular plate section that is disposed on an upper surface of the needle bar housing case and that is provided with first opening sections made at positions between an upstream grip section main body and a downstream grip section main body in a vertical direction such that a leading end of a turning arm of a turning section can be exposed to the front side, a second opening section which is provided above the first opening section and on which an upstream magnet section fronts, and a third opening section that is placed below the first opening section and on which a downstream magnet section fronts;

a plurality of thread take-up levers that are axially supported by the needle bar housing case in a swayable manner, that are provided on a front side of the needle bar housing case in an exposed fashion, and that are provided at downstream positions on needle thread paths with respect to a downstream grip section;

an upstream grip section that has

the upstream grip section main body that is placed on a front side of the plate section, that pinches to thereby grip a needle thread, and that has upstream first plate-like sections which is formed from a magnetic substance that is a material attracted by the magnet, and which is provided for the respective needle bars and an upstream second plate-like section which is provided at back side of the upstream first plate-like sections and on a front side of the second opening section and which is formed from a non-magnetic substance unattracted by the magnet, and

the upstream magnet section that is secured to the arm side and that switches between a closed state in which the needle thread is pinched and gripped between the upstream first plate-like section and the upstream second plate-like section by means of attracting the upstream first plate-like section from a back side of the upstream second plate-like section by magnetic force and an open state in which the needle thread is released from the gripped state by canceling attraction caused by magnetic force;

the downstream grip section that is placed at a downstream position along a needle thread path of the upstream grip section and that has

the downstream grip section main body which is placed below the upstream grip section main body on a front side of the plate section, which pinches to thereby grip the needle thread, and which has downstream first plate-like sections which is formed from a magnetic substance that is a material attracted by the magnet and provided for respective needle bars and a downstream second plate-like section which is provided at back side of the downstream first plate-like sections and on a front side of the second opening section and formed from a non-magnetic substance unattracted by the magnet, and

the downstream magnet section that is secured to the arm side and that switches between a closed state in which the needle thread is pinches to thereby grip between the downstream first plate-like section and the downstream second plate-like section by means of attracting the downstream first plate-like section from a back side of the downstream second plate-like section by magnetic force and an open state in which the needle thread is released from a gripped state by canceling attraction caused by the magnetic force;

needle thread supporting members that each is provided in the plate section and that each supports the needle thread in its horizontal direction at the position of the first opening section;

the turning section that turns the needle thread existing between the upstream grip section main body and the downstream grip section main body and that has the turning arm which contacts the needle thread supported by the needle thread supporting member and a needle thread motor which is secured to the arm side and which turns the turning arm; and

a control section, in a control zone for each stitch, that—in a torque control zone including at least a portion of a zone from a bottom dead point to a top dead point of the thread take-up lever during which the thread take-up lever draws the needle thread with respect to processed fabric to be sewn with the needle thread—controls the needle thread motor in accordance with a torque value in such a way that tension is imparted to the needle thread against a direction in which the thread take-up lever draws the needle thread in accordance with torque data which are generated from embroidery data and whose torque value is specified for each stitch, while the upstream grip section main body is closed and while the downstream grip section main body is opened, thereby imparting rotating force to the turning arm in an upward direction and

that—in a position control zone which is at least a portion of a zone other than the torque control zone achieved while the upstream grip section main body is opened and while the downstream grip section main body is closed detects at a starting point of the position control zone a current angle position of the needle thread motor which is a rotational position of the needle thread motor, generates angle correspondence data which specify an angle of the needle thread motor from the current angle position to an initial angle position of the needle thread motor for each angle of a main spindle motor representing a rotational position of the main spindle motor which rotates a main spindle for transmitting power to the thread take-up levers and the needle bars, controls a position of the needle thread motor to its angle of the needle thread motor corresponding to the angle of the main spindle motor as the angle of the main spindle motor changes as a result of rotation of the main spindle motor in such a way that the angle of the needle thread motor returns to an initial angle position of the needle thread motor, to thus impart rotating force to the turning arm in an upward direction and draw a needle thread from an upstream position, turns the turning arm downward so as to recede to a receded position and slides the needle bar housing case when a needle thread to be selected is changed on occasion of processing proceeding to control a next stitch, thereby letting the upstream magnet section, the downstream magnet section, and the turning arm come to a position of the selected needle thread.

18. The sewing machine according to claim **1**, wherein the control section detects a main spindle angle in accordance with zone data in which a starting point and an end point of the torque control zone and a starting point and an end point of the position control zone are specified as information about a main spindle angle that is a rotational position of the main spindle motor, thereby determining the torque control zone and the position control zone.

19. The sewing machine according to claim **1**, wherein the starting point of the position control zone corresponds to any location in a zone from the other dead point to the one dead point of the thread take-up lever and is in front of a top dead point of a shuttle, and the end point of the position control zone corresponds to any location in a zone from the one dead point to the other dead point of the thread take-up lever.

20. The sewing machine according to claim **1**, wherein a zone in which an electric current is not fed to the needle thread motor is set between the end point of the torque control zone and the starting point of the position control zone; a zone during which an electric current is not fed to the needle thread motor is set between the end point of the position control zone and the starting point of the torque control zone; the upstream grip section main body is switched to a closed state, and the downstream grip section main body is switched to an open state at the end point of the position control zone; and the upstream grip section main body is switched to an open state, and the downstream grip section main body is switched to a closed state at the end point of the torque control zone.

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